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Evaluation of Fugitive Dust Emissions from Mining

PEDCo-Environmental, Inc, Cincinnati, OH

Prepared for

Industrial Environmental Resarch Lab -Cincinnati, OH Resource Extraction and Handling Div

Apr 76

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EVALUATION OF FUGITIVE DUST EMISSIONS FROM MINING

TASK 1 REPORT

IDENTIFICATION OF FUGITIVE DUST SOURCES ASSOCIATED WITH MINING

Prepared by

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This evaluation of fugitive dust air pollution from mining operations was undertaken to identify and compile currently available information on emission sources, regulatory approaches, control techniques, and research programs related to mining activities. An analysis of the assembled information will then be used as the basis for recommending near-term research and development programs which might be implemented by IERL-Cincinnati to fill gaps in the data base and further document effective control techniques for fugitive dust from mining operations. For the more promising recommended R & D efforts, proposed technical approaches will also be developed.

This project is composed of three tasks:

Task 1: Identification of fugitive dust sources associated with mining activities

Task 2: Assessment of current status of the environmental aspects of fugitive dust

Task 3: Recommendation of promising research areas

Tasks 1 and 2 are presented in this report.

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1. INTRODUCTION

This evaluation of fugitive dust air pollution from mining operations was undertaken to identify and compile currently available information on emission sources, regulatory approaches, control techniques, and research programs related to mining activities. An analysis of the assembled information will then be used as the basis for recommending near-term research and development programs which might be implemented by IERL/Cincinnati to fill gaps in the data base and further document effective control techniques for fugitive dust from mining operations. For the more promising recommended R & D efforts, proposed technical approaches will also be developed.

The project is composed of three tasks, each of which will have its own task report:

Task 1 - Identification of fugitive dust sources associated with mining activities.

Task 2 - Assessment of current status of the environmental aspects of fugitive dust.

Task 3 - Recommendation of promising research areas.

The project is similar in scope to a study recently completed by Monsanto Research Corporation.[1] However, the intent of the present contract is to provide recommendations for specific research programs while the Monsanto Research study was designed to compile preliminary data on fugitive dust emissions from open sources and to recommend other sources for testing. Therefore, only the first of the three tasks overlaps to any extent with this previous work; their work has been utilized in preparing the Task 1 report.

The present Task 1 report summarizes current knowledge concerning fugitive dust sources at mines and ranks the identified sources in order of relative importance from the standpoints of air quality impact and need for further research. Data for the report were obtained from a literature search and from PEDCo's files on fugitive dust sources. The literature search was not intended to be exhaustive, but to be thorough enough to uncover all studies in which fugitive dust emissions from mining operations were quantified by a reasonably accurate procedure. In this task, primary importance was attached to the identification of all mining activities that are major dust sources and the estimation of representative emission rates from these various sources.

The scope of the project includes both surface and underground mining plus related operations normally performed at the mine sites, such as crushing and storage. It does not include dust that is generated and remains underground or in an enclosed area--only emissions that affect ambient air quality. Also, it does not include emissions which occur off-site during shipping or at distant processing plants. Almost all particulate emissions at mines would be categorized as fugitive dust since they are generally emitted at ground level as a result of equipment activity or material transfer rather than from stacks.

This report is divided into three chapters following the Introduction. Chapter 2 describes four major mining industries (coal, copper ore, rock quarrying, and phosphate rock) and the sizes and geographic distribution of their mines. Chapter 3 describes 11 different mining operations which are responsible for significant fugitive dust emissions in one or more of the major mining industries, and presents estimates of emissions from each of these operations. The final chapter summarizes those operations which have the greatest air quality impacts and those for which additional emission data are most needed.

2. MAJOR MINING INDUSTRIES

The four mining industries which are probably the largest sources of fugitive dust nationally are coal, copper, crushed stone, and phosphate rock mining. These industries are each described briefly in this chapter to provide a basis for evaluating the extent and impacts of fugitive dust air pollution from mining operations.

All four of these materials are mined primarily in surface mines, which have far more potential for fugitive dust emissions than underground mines. In addition, the tonnages removed from these mines are generally greater than for other minerals and ores. Some other materials which were also considered because of their large tonnages and surface operations are iron, oil shale, and sand and gravel. Iron ore mining was eliminated because ferrous metals are not within the purview of the Resource Extraction and Handling Division of the Cincinnati Industrial Environmental Research Laboratory, EPA, the sponsoring group for this work. Oil shale was not included because there are presently no large-scale oil shale surface mines in operation. Sand and gravel mining was not included because much of this material is mined and processed wet and is therefore nondusting.

Mines other than the four types used as examples here can certainly be major fugitive dust sources. They have the same unit operations and points of dust release, so their emissions can be estimated by comparison with any one of the four mining industries for which data have been assembled.

2.1 COAL MINING

There were 603.4 million tons of bituminous coal and lignite mined in the U.S. in 1974 in a total of 5,247 mines. Of these mines, 3,208 were surface mines and 2,039 were underground. Production from surface mines surpassed underground mines in 1974 for the first time, accounting for 54 percent of the total.[2]

The 50 largest coal mines and their 1973 and 1974 production rates are listed in Table 2.1. These mines, 34 surface mines and 16 underground, produced 24.6 percent of the coal mined in 1974. Their locations are shown in Figure 2.1. They are concentrated in the coal mining areas of Appalachia, the Central states, the Northern Great Plains, and the Four Corners area. All of the Western mines shown, plus those in Indiana, Ohio, and most of those in Kentucky are surface mines.

Although total coal production has been relatively stable for several years, there has been a definite shift from the East and from underground mines to the strip mines of low sulfur coal in the West. This trend is expected to accelerate in the future with the opening of giant new mines in Powder River Basin, northwestern Colorado, the Four Corners area, and the lignite fields of North Dakota and eastern Montana. Many of these mines will be used to supply coal gasification plants and mine-mouth power plants.

The most unique aspect of surface coal mining is the huge amount of earth moving associated with it. The overburden removal operations to get to the coal seams dwarf previous major earth moving projects such as canals and dams. A new generation of larger earth moving equipment was developed to handle this task.

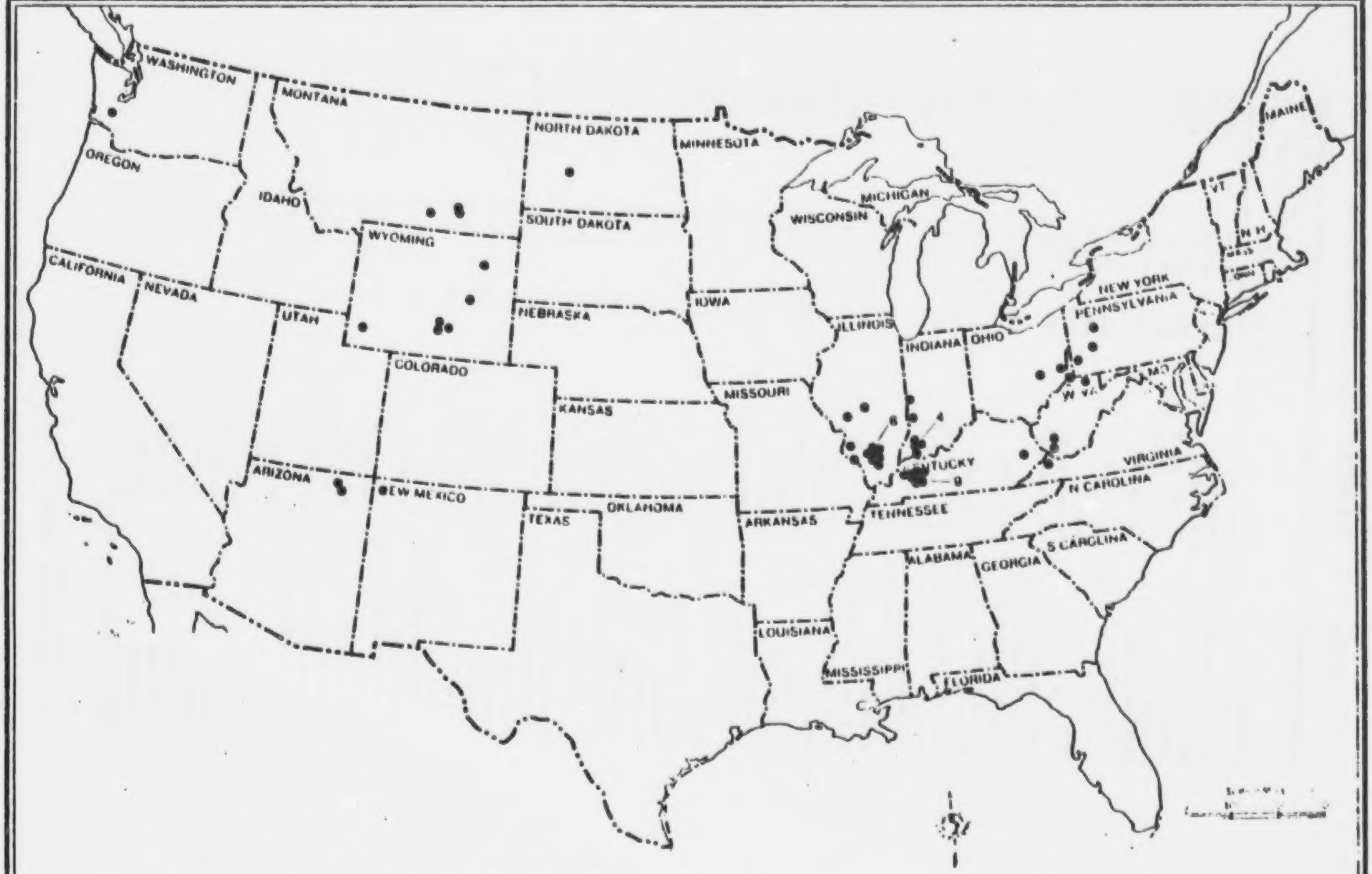
Trucks are used at almost all surface mines to transport the coal from the mine to the processing area or loading ramp. For shipment to consumers, railroads are the most

Table 2.1 LARGEST U.S. COAL MINES

Company	Mine	State	Est. production, 10^3 ton/yr 1974	1973
Utah International	Navajo[s]	NM	6955	7389
Decker	Decker No. 1[s]	MT	6786	4159
Peabody	River King[s]	IL	6474	6526
Peabody	River Queen[s,u]	KY	4703	4172
Southwestern Illinois	Captain[s]	IL	4347	4451
Peabody	No. 10[u]	IL	4132	4147
C&K	Fox[s]	PA	4000	2620
Peabody	Black Mesa[s]	AZ	3933	3247
Washington Irrigation Dist.	Centralia[s]	WA	3890	3229
Clinchfield Div., Pittston	Moss No. 3[u]	VA	3679	3903
Peabody	Sinclair[s]	KY	3529	5291
Central Ohio	Muskingum[s]	OH	3367	3668
Amax	Belle Ayr[s]	WY	3313	898
Consolidation, Central Division	Egypt Valley[s]	OH	3253	4257
Peabody	Lynnville[s]	IN	3232	4065
Western Energy	Colstrip[s]	MT	3213	4254
Arch Minerals	Seminoe No. 1[s]	WY	3142	2865
Amax	Leahy[s]	IL	2834	2942
Peabody	Universal[s]	IN	2833	3044
U.S.Steel	Robena	PA	2815	2871
Peabody	Ken[s,u]	KY	2793	3202
Pacific Power & Light	Dave Johnston[s]	WY	2687	2897
Amax	Ayrgem[s]	KY	2685	3206
Arch Minerals	Seminoe No. 2[s]	WY	2590	1498
Peabody	Camp No. 1[u]	KY	2528	2620
Peabody	Kayenta[s]	AZ	2515	-
Monterey	No. 1	IL	2480	2695
Inland Steel	Inland	IL	2469	2588
Kemmerer	Sorensen[s]	WY	2437	2546
Amax	Ayrshire[s]	IN	2404	250
Consolidation, Mountaineer Div.	Robinson Run[u]	WV	2380	2401
Old Ben	Old Ben No. 1[s]	IN	2345	2396
Peabody	Big Sky[s]	MT	2229	1972
Peabody	Homestead[s]	KY	2194	2449
Island Creek	Pevler No. 1[s,u]	KY	2189	1733
Consolidation, Christopher Div.	Humphrey No. 7[u]	WV	2155	2692
Consolidation, Mountaineer Div.	Loveridge[u]	WV	1985	2185
Rosebud	Rosebud[s]	WY	1963	1510
Old Ben	No. 24[u]	IL	1960	2377
Freeman	Orient No. 3[u]	IL	1919	2207
Consolidation, Ohio Valley Div.	Ireland[u]	WV	1860	2343
Peabody	Vogue[s]	KY	1814	2412
Mathies	Mathies[u]	PA	1809	2036
Peabody	Star[u]	KY	1808	1999
Amax	Wright[s]	IN	1790	2097
Amax	Minnehaha[s]	IN	1790	2012
Mountain Drive	Mountain Drive[s]	KY	1765	1663
Old Ben	No. 26[u]	IL	1739	2100
Peabody	Baldwin[u]	IL	1727	1291
Knife River	Beulah[s]	ND	1722	1726

[s] strip mines
[u] underground mines

Source: Bituminous Coal Data, 1974 Edition, National Coal Association, Washington, D.C., 1975.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GEORGIA
LOUISIANA
MISSISSIPPI
FLORIDA

Figure 2.1. Locations of largest U.S. coal mines.

common means with 66 percent of the tonnage in 1974. Almost 40 percent of this amount was in unit trains. The remainder of coal shipment is evenly divided among barges, trucks, and mine-mouth operations (with 11 percent each). All other modes of transportation account for less than one percent.[2]

2.2 COPPER MINING

Domestic mine production of recoverable copper in 1975 was 1.41 million tons, down sharply from the 1.60 million tons in 1974 and 1.72 million tons in 1973 as a result of decreased demand for copper products. The principal copper-producing states were Arizona, with 56.6 percent of the total, Utah (12.7%), New Mexico (10.4%), Montana (7.2%), Nevada (5.6%), and Michigan (5.2%).[3] The largest 25 copper mines, which provided 89 percent of the total production in 1973, are listed in Table 2.2. Their locations are shown in Figure 2.2.

Open pit mines accounted for 83 percent of mine output and underground mines for 17 percent. The production of copper from leach pads and in-place leaching (mainly recovered by precipitation with iron) was 160,000 tons in 1973, or 9 percent of the output from the mines.[3]

As indicated from the above data, copper mining is characterized by very large mines of relatively low grade ore rather than many small mines in rich veins. The average yield nationally of copper in copper ore was only 0.53 percent. This low grade ore necessitates the handling of large quantitites of material in the mining and processing steps. Also, wide variations in copper content within the ore body may require the mining and handling of additional amounts of waste material that is too low in copper content to justify recovery.

Table 2.2 LARGEST U.S. COPPER MINES, 1973

Company/Mine	Estimated production, tons	State	County
Kennecott Copper Utah Copper	255,000	Utah	Salt Lake
Magma Copper San Manuel	158,300[a]	Arizona	Pinal
Phelps Dodge Morenci	119,500	Arizona	Cochise
Anaconda Berkeley Pit	127,800[a]	Montana	Silver Bow
Phelps Dodge Tyrone	104,000	New Mexico	Grant
Kennecott Copper Ray Pit	98,900	Arizona	Pinal
Cyprus Mines Pima	88,100	Arizona	Pima
White Pine Copper White Pine	76,600	Michigan	Ontonagon
Duval Sierrita Sierrita	NA	Arizona	Pima
Kennecott Copper Chino	67,800	New Mexico	Grant
Anamax Mining Twin Buttes	73,600	Arizona	Pima
Phelps Dodge New Cornelia	53,800	Arizona	Pima
Inspiration Copper Inspiration	43,100	Arizona	Gila
Asarco Mission	46,600	Arizona	Pima
Kennecott Copper Ruth	50,000	Nevada	White Pine
Anaconda Yerington	35,800	Nevada	Lyon
Asarco Silver Bell	23,800	Arizona	Pima
Anaconda Butte Hill	NA	Montana	Silver Bow
Cities Service Copper Cities	NA	Arizona	Gila
Duval Mineral Park	NA	Arizona	Mohave
Magma Copper Magma	NA	Arizona	Pinal
Phelps Dodge Copper Queen	NA	Arizona	Cochise
UV Industries Continental	NA	New Mexico	Grant
Bagdad Copper Bagdad	NA	Arizona	Yavapai
Duval Esperanza	NA	Arizona	Pima

[a] This figure includes underground as well as open pit production.

NA = not available

Source: Preprint from the 1973 Bureau of Mines Minerals Yearbook, Copper, U.S. Department of the Interior, Bureau of Mines, Washington, D.C., 1973, pp 2-5.

Source: Fugitive Dust from Mining Operations, Monsanto Research Corporation, Dayton, Ohio, prepared for U.S. Environmental Protection Agency, 1975.

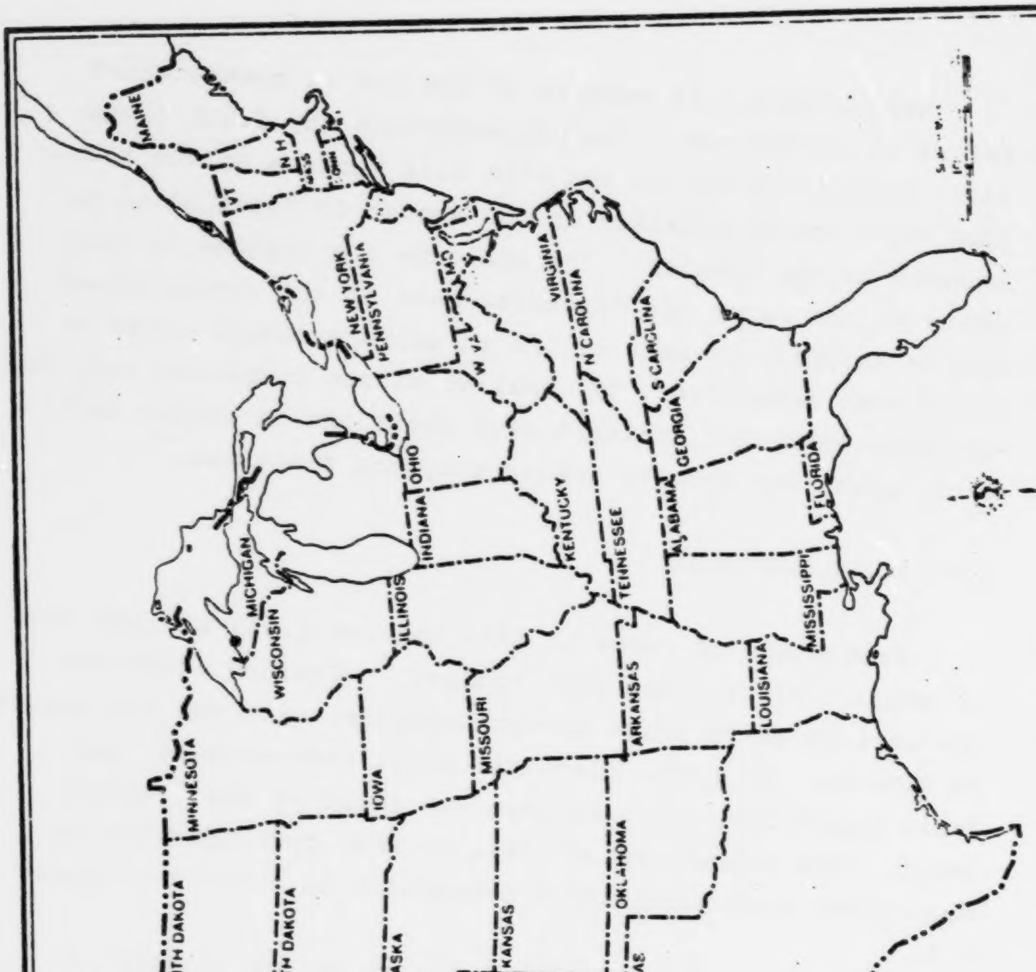
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Figure 2.2. Locations of largest U.S. copper mines.

Approximately 94 percent of the ore is concentrated before it is smelted. The concentration (by froth flotation) usually occurs at the mine site because of the reduction that can be obtained in the amount of material to be shipped to the smelter. The smelters are located in proximity to the major ore deposits; most of the concentrated ore is shipped via unit trains on private tracks owned by the copper companies. The smaller mining companies that do not have their own smelters send their ore to custom smelters, which may involve longer shipping distances.

2.3 STONE QUARRYING

Production of stone in 1974 totaled 1.044 billion tons of which 1.042 billion were crushed.[4] Crushed stone was produced in every state except Delaware, with the six states of Florida, Illinois, Missouri, Ohio, Pennsylvania, and Texas accounting for more than one third of the national total. The percentage of total crushed rock quarried in each state with significant production is shown in Figure 2.3.

There were 5,431 active quarries in the country in 1974. Of these, 228 mined at least 900,000 tons during the year and accounted for 37 percent of the domestic production.[4] Stone quarrying tends to be an industry of smaller operations serving local and regional needs.

Almost all stone quarries are open pit mines. Blasting is normally used in quarrying crushed rock. Other equipment such as rippers and hydraulic excavators may be used to break the rock loose. Surge piles between the quarrying and the crushing/sizing operations are also quite common.

Most of the crushed rock is used for construction-related purposes such as roadbases, concrete aggregate, or cement manufacture. In many cases, pits or quarries may be

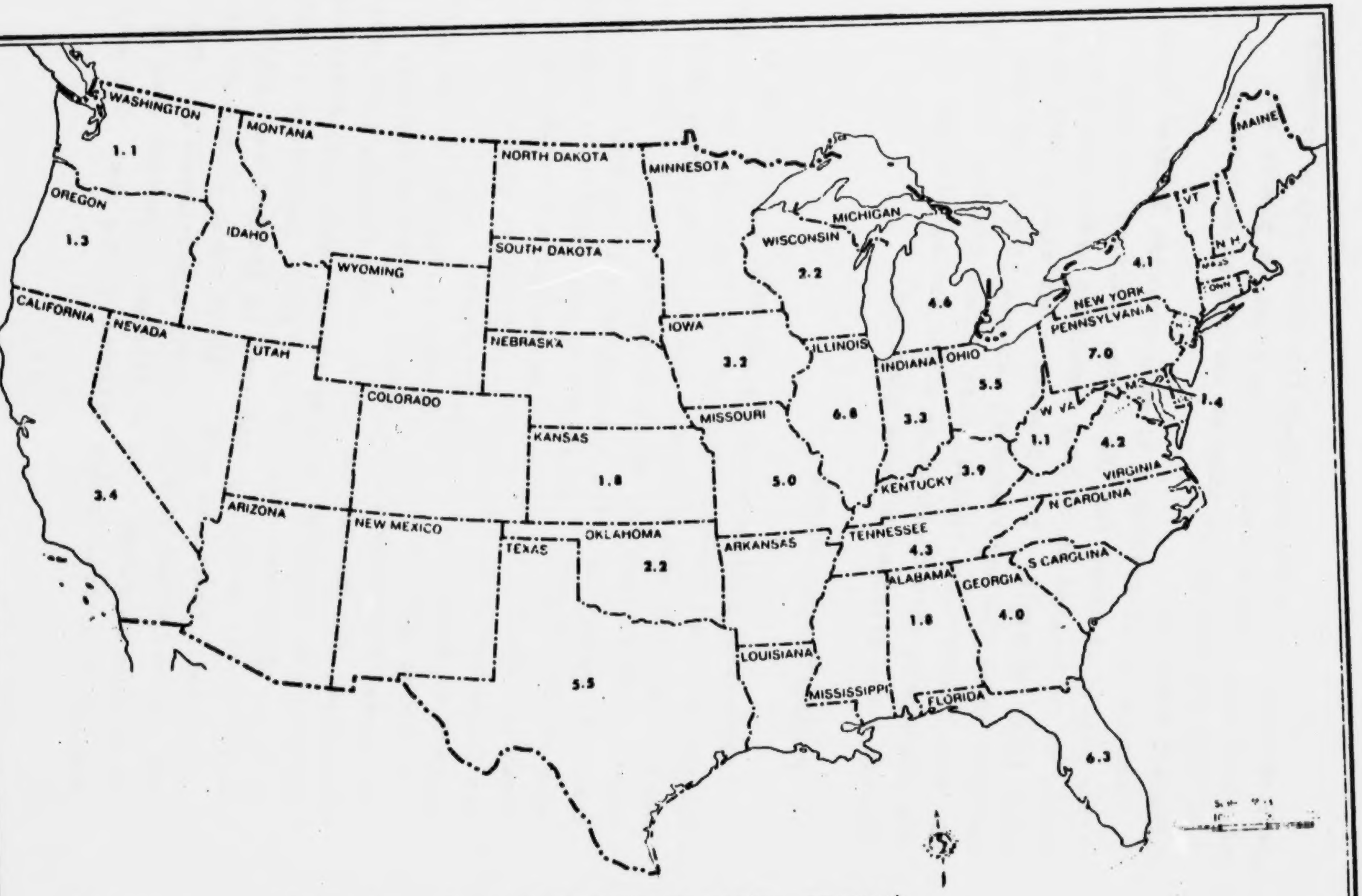
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Figure 2.3. Production of crushed rock by state, percent.

operated in conjunction with specific construction projects and mined only intermittently. The crushing plants are often portable and may be used to service as many as 10 different quarries.

Because it is desirable to have quarries located close to the points of usage for the stone, quarries are more likely to be located in or near populated areas than are other types of mines. This proximity has also caused more concerns about the environmental impacts of quarries than the more remote mines--noise, dust, truck traffic, blasting, and inadequate site reclamation after mining have all created local problems at some quarries.

2.4 PHOSPHATE ROCK MINING

Marketable phosphate rock production in 1975 was 48.8 million tons, an increase from the 45.7 million tons of 1974 and 42.1 million tons of 1973. Mining of phosphate rock is concentrated in Florida, which accounted for 77.7 percent of the total output in 1975, and particularly in Polk County in west central Florida. Locations of the largest 24 mines are shown in Figure 2.4, and their estimated production rates are presented in Table 2.3. These 24 mines accounted for 77 percent of phosphate rock mined in 1975.[5]

Mining procedures are somewhat different for the different types of phosphate rock deposits found in Florida, Tennessee, and the Western states. The Florida land pebble deposits are contained in a matrix of sandy clay averaging 16 ft in thickness, overlain by a 20 ft overburden of sandy soil.[6] Prior to mining, the land is drained and vegetation is removed. Draglines with 35 to 55 cubic yd buckets strip the overburden and mine the matrix simultaneously. The overburden is dumped into an adjacent mined-out area or stacked on natural ground adjacent to the cut. The matrix

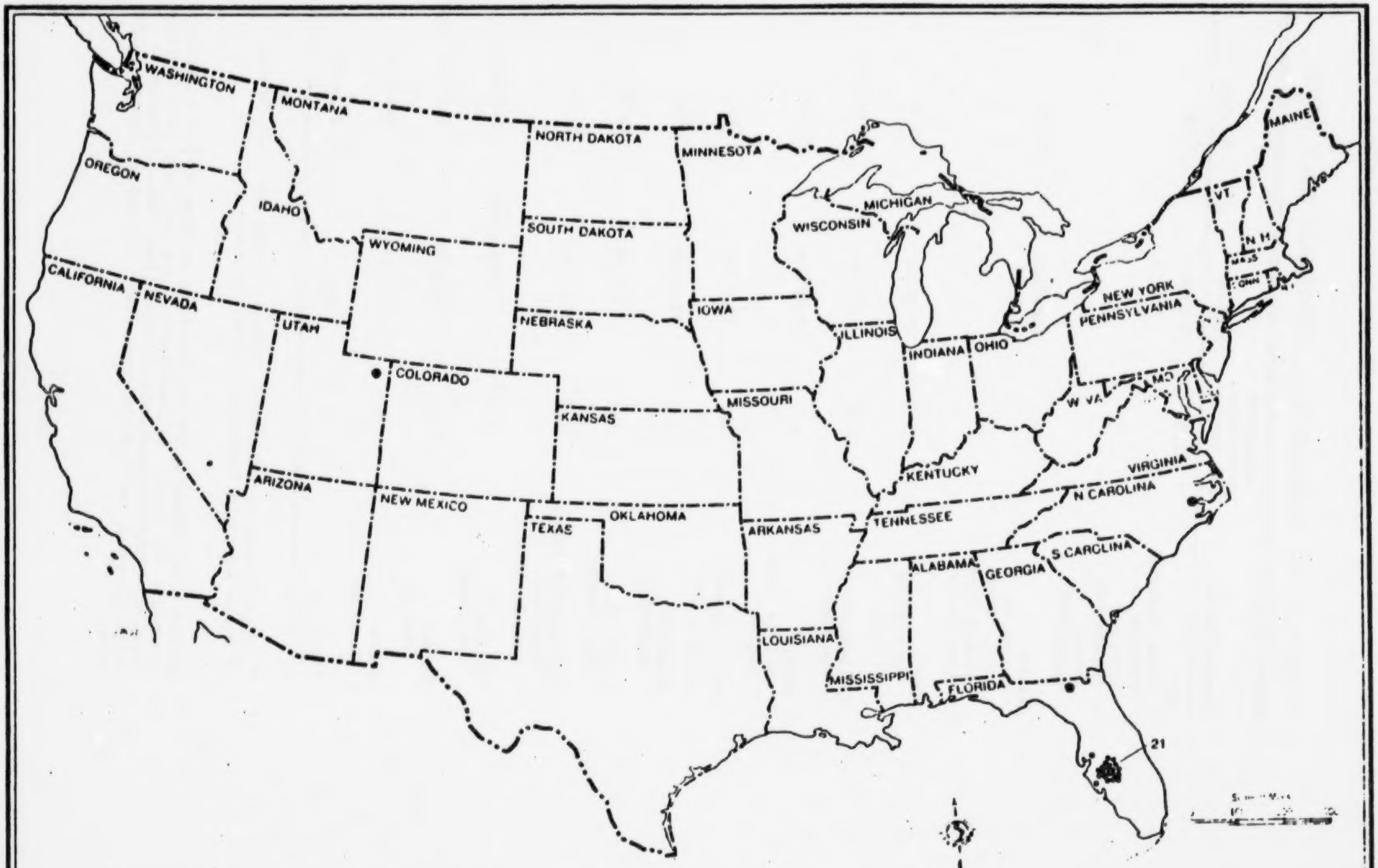
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Figure 2.4. Locations of largest U.S. phosphate rock mines.

Table 2.3. LARGEST U.S. PHOSPHATE ROCK MINES, 1975

Company/Mine	Estimated production, 10^6 ton/yr	State	County
IMC	11.0	Florida	Polk
Clear Springs			
Noralyn			
Homeland			
Phosphoria			
Achan			
Kingsford			
Agrico	7.0	Florida	Polk
Palmetto			
Payne Creek			
Saddle Creek			
Fort Green			
Mobil			
Fort Meade	3.3	Florida	Polk
Nichols	1.2		Polk
Occidental	3.5[a]	Florida	Hamilton
Suwannee			
Swift	2.6	Florida	Polk
Silver City			
Watson			
W. R. Grace	2.5	Florida	Polk
Bonny Lake			
Brewster	1.8	Florida	Polk
Haynsworth			
Gardinier	1.8	Florida	Polk
Fort Meade			
USS-AgriChemicals	1.2	Florida	Polk
Rockland			
Lake Hancock			
Texasgulf	0.5[a]	N. Carolina	Beaufort
Lee Creek			
Borden	0.4	Florida	Hillsborough
Tenoroc			
Beker	0.4	Florida	Manatee
Manatee			
Stauffer	0.4[a]	Utah	Uintah
Vernal			

[a] This figure is 1973 data, Preprint from the 1973 Bureau of Mines Minerals Yearbook, Phosphate Rock, pp. 3-5.

Source: Particulate and Sulfur Dioxide Area Source Emission Inventory for Duval, Hillsborough, Pinellas, and Polk Counties, Florida, PEDCo-Environmental Specialists, Inc., Cincinnati, Ohio, prepared for U.S. Environmental Protection Agency, June 1975.

is deposited in a previously prepared sluice pit where hydraulic guns slurry it. The slurry is pumped for distances up to six miles to a washing plant.

Phosphate rock ore in Tennessee is stripped and mined from consolidated deposits with 2 or 3 cubic yd draglines, then trucked to the processing plant.

In Western states, all phosphate ore is strip mined except for two underground mines in Montana. Mines in southeastern Idaho use scrapers, bulldozers, or power shovels to remove overburden and mine the ore. Phosphate rock in Utah is quarried after an overlying limestone layer is drilled, blasted, and removed. Ore mined in Western states is either hauled by truck or moved by rail to processing plants.

In the period 1971 to 1975, demand for phosphate rock worldwide exceeded production capacity, reversing a condition of oversupply that characterized the industry for the previous five years. Indications of reduced demand and resistance to higher prices were noted in 1975. Mining capacity now appears capable of satisfying anticipated demands. Florida output is projected to steadily increase to a level of about 55 million tons per year by 1980 and remain near that level for 10 to 20 years.[6]

3. MINING OPERATIONS WITH POTENTIAL FOR FUGITIVE DUST

There is no established classification of mining operations. The Council on Environmental Quality Report to Congress[7] on coal surface mining and reclamation identified nine discrete operations associated with surface mining: construction of access roads, scalping or clearing of vegetation, drilling and blasting to fracture the overburden, removal and placement of overburden, removal of the coal, rehandling and grading of the overburden, revegetation, water drainage control, and sediment basin construction. In an air quality study of mining,[8] Environmental Research and Technology described the operations somewhat differently: topsoil removal and placement, overburden removal and redistribution, coal removal and transport, conveying, sorting, crushing, storage, vehicular traffic on unpaved roads, and coal fires.

The breakdown of operations used in this report is oriented toward isolation of specific dust-producing activities. For each of the 11 operations identified (see Table 3.1), the operation is described and all available emission estimates compiled and compared. Also, variables on which the emission rate is dependent are discussed, e.g., climate and size of material being handled.

All of the 11 operations are not found in every type of mine, and in some cases the operation is only a significant dust source at one type of mine. The operations that are usually dust sources within a particular mining industry are shown in Table 3.1.

Table 3.1. DUST-PRODUCING OPERATIONS BY MINING INDUSTRY

Operation	Mining industry Coal	Copper	Rock	P_2O_5 rock
Overburden removal	x	+	+	x
Blasting	+	x	x	o
Shovels/Truck loading	x	x	x	o
Haul roads	x	x	x	o
Truck dumping	+	x	x	o
Crushing	+	+	x	o
Transfer & conveying	+	+	+	x
Cleaning	o	o	o	o
Storage	+	+	x	x
Waste disposal	+	x	o	+
Reclamation	x	o	+	x

x = usually a major source

+ = a minor or occasional source

o = usually not a dust source

In estimating the total fugitive dust emissions from a mine, it is preferable to identify the dust-producing activities present and estimate emissions for each one separately rather than to use a single emission factor for the entire mine. The former procedure permits direct determination of the major source areas--the ones needing control--and results in accurate assessments even if the mine has some atypical processes.

3.1 OVERBURDEN REMOVAL

Description

Overburden removal is an operation in almost all surface mining and entails removal of all topsoil, subsoil, and other strata overlying the deposit to be mined. Significant advances in methods of surface mining have occurred in recent years with the development of giant excavating and hauling equipment designed specifically for these operations.

In 1965, coal surface mining was not considered feasible unless the overburden depth to seam thickness was 10:1 or less--i.e., a coal seam five feet thick to justify removal of 50 ft of overburden. With introduction of the larger equipment, this range of overburden to seam thickness has increased to as much as 30:1. Removal of up to 200 ft of overburden is now feasible for coal mining, while the average in 1965 was 48 ft.[9]

There are three major types of coal strip mining--area, contour, and auger. Area strip mining is used where the terrain is relatively flat. Large-scale excavation equipment, usually draglines, remove the overburden material and deposit it in spoil banks in a trench left by the previous strip. Thus, only the initial strip produces waste overburden that must be disposed of or stored for land reclamation. Trenches excavated by draglines are normally about 100 to 200 ft wide.

On land to be mined with slopes greater than about 15 degrees, contour strip mining is usually employed. In this mining method, the overburden is removed from the slope to create a flat excavation, or bench, resulting in a vertical highwall on one side and a downslope pile of spoils on the other side. The exposed deposit is then mined and the land reclaimed by backfilling the previously worked area with newly removed overburden. If a pattern of backfilling to the original or similar contour is carried out concurrently with the mining and the backfilled land is revegetated, the mined area can usually be successfully reclaimed. Leaving the spoils on the downslope can result in landslides and prevent reclamation.

The third type of strip mining--auger mining--is usually done in conjunction with contour mining. The deposit exposed in the highwall by the contour method is mined by using large drills or augers to pull the deposit horizontally from the seam.

A national bill to regulate surface mining of coal has been passed by the Congress on two different occasions. However, because of steep slope performance standards contained in both bills, the President has vetoed them. The two states where the majority of contour and auger coal mining methods are used, Pennsylvania and West Virginia, have laws prohibiting spoils on downslopes. In West Virginia, all but the last 20 feet of the highwall must be covered and in Pennsylvania all of the highwall must be re-covered.

Increasingly, as demand for complete land reclamation grows, the overburden material is segregated by removing topsoil and other subsoil components suitable for revegetation, storing them separately, and then covering the contoured spoil banks with these two layers during the reclamation process. This greatly increases the ability to revegetate and reclaim the land. It also increases the time and cost of overburden removal, with the need for bulldozers and scrapers for removing up to five feet each of topsoil and other subsoil strata and transporting this soil to storage areas.

For other types of surface mining such as open pit mining and quarrying, overburden removal may be only a one-time or occasional operation rather than continuous. For these types of mines, the deposit to be removed is of the same magnitude or larger than the overburden volume and the location of the mining activity is relatively fixed. Therefore, the overburden is removed permanently and may be transported off-site for disposal.

In excavating overburden, three kinds of equipment are used in typical surface mining operations:

- Draglines
- Shovels
- Small mobile tractors, including bulldozers, scrapers, and front-end loaders

Most surface mining operations use these equipment items in varying combinations.

Draglines are electrically powered equipment capable of moving large amounts of material with a bucket capacity ranging from 30 to 220 cu yd (overburden has an average density of 1.3 ton/cu yd). The dragline moves along the surface or bench, positions its bucket on the overburden to be removed, and loads it by dragging it toward the machine. The loaded bucket is then lifted, the machine rotated, and the bucket dumped in an area that has already been mined.

Alternately, the excavated material may be temporarily stockpiled and moved to a final disposal site by loading onto trucks.

Shovels are large diesel or electrically powered stripping equipment used in surface mines for a number of years and specifically designed for a particular mine operation. These machines proceed along a bench scooping up fragmented overburden in buckets with capacities of up to 130 cu yd. In the largest surface mines, shovels are often used in conjunction with draglines.

Tractors are typically used either in small mines or in conjunction with larger, more specialized equipment in large mines. The principal advantages of tractors are their maneuverability, ability to negotiate steep grades, and capability to dig and transport their own loads. They are used for a variety of tasks, including clearing, topsoil removal, preparing benches, and leveling spoil piles.

A fourth type of excavation equipment, the bucket wheel excavator, is seldom used in this country. It has a rotating bucket wheel mounted at the end of a boom up to 400 ft long. As the wheel rotates, the buckets along the perimeter are loaded when they cut into the deposit with an upward motion. Continuing rotation causes the buckets to be inverted and empty onto a conveyor which then transports the material to a disposal area. Only very large mines with suitably soft overburden material can justify the expense of this equipment.

Emission Estimate

The two primary fugitive dust sources associated with overburden removal are:

- Dumping of dragline buckets or shovels full of overburden material into adjacent trenches or spoil banks, as shown in Figure 3.1.
- Operation of scrapers and bulldozers in topsoil and subsoil removal and transfer.

If the overburden material must be transferred to trucks for removal, the emissions from loading, travel on haul roads, and dumping are considered under these other mining operations.

No sampling specifically for either of these two sources has been done. However, some emission estimates have been made. Hittman estimated 0.002 lb/ton of coal mined as the average emission factor nationally for excavation at coal surface mines where area stripping was used, and 0.003 lb/ton of coal with contour stripping.[9] For uncontrolled mining in the Southwest (primarily the Four Corners area), their estimate was 0.26 lb/ton of coal; with controls (assumed to be watering), fugitive dust emissions were estimated to be 0.009 lb/ton of coal. Battelle estimated the total fugitive dust emissions from surface mining of coal in Western states to be 0.1 lb/ton of overburden removed and indicated that overburden removal was the largest emission source at these mines.[10] Considering the common ratios of overburden removed to coal mined (5:1 to 20:1), Battelle's factor appears to be an order of magnitude higher than Hittman's value. From both of these references, it can be concluded that emissions from strip mining and particularly the overburden removal process vary considerably geographically, presumably because of the much drier climate in the Western states.

PEDCo estimated that the dragline operation at a lignite surface mine in North Dakota had an emission rate of 0.05 lb/ton of ovarburden removed, primarily resulting from

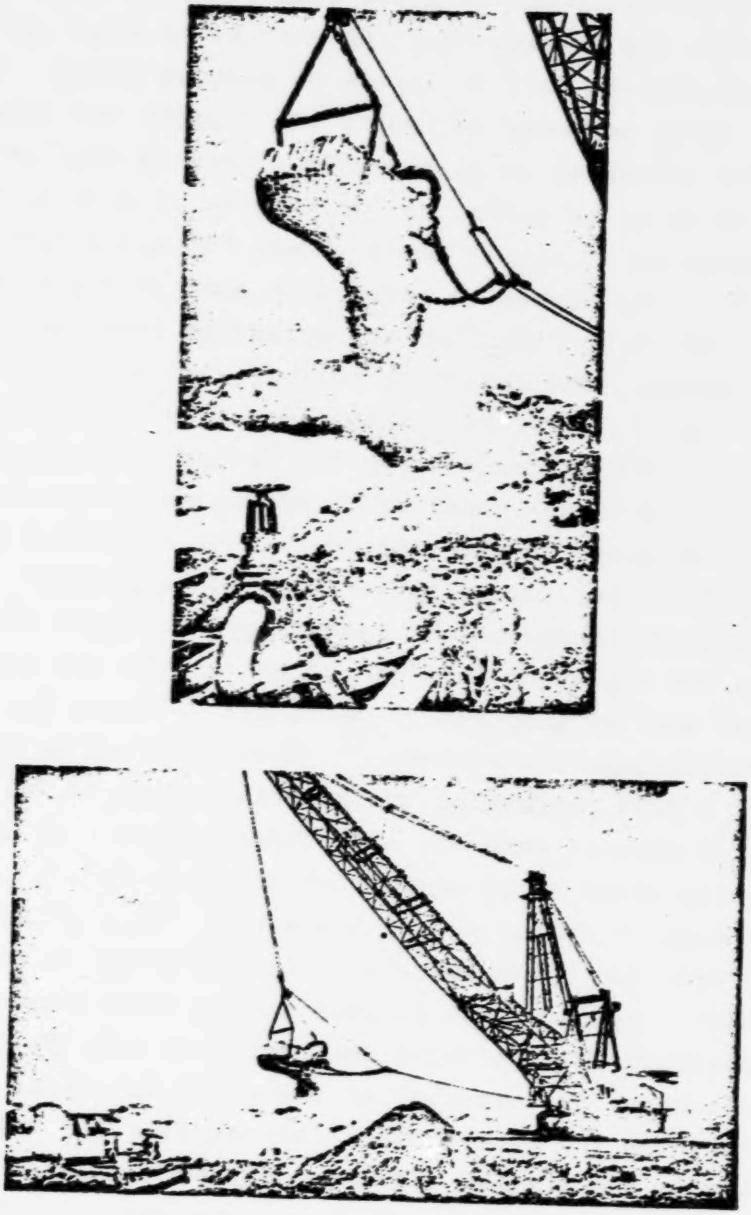


Figure 3.1. Overburden removal.

Source: Phosphate, Florida Phosphate Council, p 6.

dumping of the excavated material from a height of at least 100 feet into the trench. For the particular mine surveyed, this was equivalent to 0.42 lb/ton of lignite mined. In addition, three scrapers stripping the topsoil and subsoil layers were estimated to each produce fugitive dust emissions of 16 lb/hr of operation, or a total of 0.03 lb/ton of lignite mined on an annual basis. These estimates were made by comparison with emission rates from similar fugitive dust sources, such as construction and aggregate handling, which had been tested. The resulting emission estimates of 0.45 lb/ton of lignite or 0.054 lb/ton of overburden removed compare well with Battelle's average factor if it is assumed that about half of the total strip mining emissions result from the overburden removal operation (the value was 63 percent for the particular mine that PEDCo surveyed).

Engineering Research and Technology (ERT) has provided input[8] to the Bureau of Land Management on the air quality aspects of coal development in northwest Colorado for an environmental impact statement.[11] They proposed an emission factor of 0.0024 percent of the material moved (0.048 lb/ton) for topsoil removal, overburden removal, or coal removal, including a correction for climatic conditions and control measures (watering) at the mines. This emission rate was obtained by applying a published emission factor[12] for aggregate handling and storage to the overburden handling operation, but reducing that emission rate by a factor of three because the material at the mines is coarse broken rock containing few fines rather than aggregate. This emission rate was further reduced to account for lack of fugitive dust on wet or frozen days. The resulting factor agrees quite well with the PEDCo value for mining in a similar climatic area, especially considering the rather crude methods of approximation used in both cases.

Overburden removal for copper mining, rock quarrying, and phosphate rock mining may be much less of a fugitive dust source than in coal mining for several reasons:

- Much less overburden material is handled in open pit mines and quarries.
- If the overburden material is to be removed permanently, no segregation and separate handling of topsoil fractions is required.
- Phosphate rock deposits in Florida and other Southeastern states are generally mined in areas where the water table is near the surface and the overburden has a high moisture content and therefore does not produce dust when moved. Average overburden depths in Florida are about 20 ft.
- If the overburden depth is fairly shallow, the excavated material will not be dropped as far from the dragline bucket or shovel to the trench or spoil bank, creating less of an impact and less opportunity for dispersion of airborne material.

PEDCo estimated particulate emissions from dragline operations at an open pit copper mine in Butte, Montana to be 29 ton/yr.[13] No data were obtained on the amount of overburden removed annually; the emission rate per ton of ore mined was 0.0008 lb, almost negligible in comparison with the factor for coal mining. The excavation area was noted to be moist and nondusting; emissions were estimated by assuming the active dragline operation of 2 acres to be equivalent to an active construction site, using an emission factor of 1.2 ton/acre/month.

The Battelle, PEDCo, and ERT data show that overburden removal is potentially one of the largest fugitive dust sources at surface mines. It is also one of the most variable. The dust losses from this operation vary with the composition and texture of the overburden material, its moisture content, excavation procedures, equipment employed, etc. For any specific mine, the emission rate is probably most closely related to the amount of overburden moved.

3.2 BLASTING

Description

Drilling and blasting are done to fracture hard, consolidated material so it can be removed more easily and efficiently by the excavating equipment. Blasting may be needed for certain impenetrable overburden or for partings between the seams being mined, but more commonly to loosen the deposit itself. This operation is a routine part of open pit mining and quarrying; its use in surface coal mining is dependent on the depth and hardness of both the overburden and the coal bed; it is almost never required with phosphate rock mining.

The blastholes are drilled from the surface of the rock layer or deposit to the depth to which the deposit is to be broken. Shelves of 30 to 50 ft depth are often used if a deposit of greater thickness is being mined. A flat bench is first prepared for the drilling rig, which is mounted on a tractor or truck. The holes are drilled in a predetermined pattern by an electrically-powered rotary drill 4 to 15 inches in diameter. Larger holes (containing more explosives) are drilled for fracturing rock than for breaking coal. Typical blasting patterns range from 20 ft by 20 ft to 50 ft by 100 ft, with the blasthole spacings varying with the material to be fractured. When a particularly resistant rock formation is encountered, a pneumatic drill may be required.

Normally, the explosive is a mixture of ammonium nitrate and fuel oil. Either dynamite or metalized mixtures such as ammonium nitrate and aluminum can be used when a more powerful explosive is required. From 300 to 11,000 lb of explosives are charged into each hole, depending on its depth, location in the pattern, and the material encountered in drilling. Millisecond delays in the blasting sequence are programmed to maximize the breaking effect and to minimize seismic shock. Mats may be used with small blasts to reduce the scattering of rock fragments during the blast.

The frequency of blasting is rarely more than once per day and may be much less often. For reasons of safety and to minimize disruption of other mining activities, blasting is usually conducted between work shifts. The area to be blasted must also be cleared of equipment and workers during the time that the holes are being charged and wired for detonation, so drilling and blasting are generally as isolated from the other active mining operations as possible.

Emission Estimate

Sampling of drilling and blasting operations at one granite quarry indicated emission rates of 0.0008 lb/ton of granite quarried for drilling and 0.16 lb/ton due to blasting.[14] Of 11 different processes sampled at the quarry (not the same 11 mining operations described herein), blasting produced the most emissions, accounting for 63 percent of the total fugitive dust emissions from the quarry and crushing plant. More explosive charge is required for blasting granite than other ore. Based on the results, of this study, the research firm that conducted the sampling, Monsanto Research, has scheduled further field testing of emissions from blasting.

PEDCo estimated emissions from daily blasting at a large open pit copper mine to be about 200 lb of suspended material per blast, or about 0.001 lb/ton of ore. This estimate was based on visual observation and was noted to be only an order of magnitude value. The large difference between the two available emission factors could be due to unreliability of the PEDCo estimate or to actual differences between the amounts of dust generated by the two blasting operations. The additional scheduled testing may resolve this question.

Blasting is a difficult operation to sample because of its short duration and the danger of placing sampling equipment or men close enough to the area of the expected plume prior to the blast. Also, the force of the blast throws much material into the air that is larger in particle size than suspended particulate. Distinction of this settleable material (which may have a much greater mass) from the suspended fraction may not be possible at the time of the sampling; particle sizing analysis on the collected sample and correction for the percent by weight of settleable particulate may be necessary. Observation of film footage of blasting shows that much of the fine dust that remains airborne is actually generated as the blasted rock returns to the surface after being lifted by the force of the blast, not by the initial explosion.[15] The drilling part of this operation is amenable to conventional open source sampling methods, but these emissions are probably negligible compared to emissions from blasting.

The dust plume from a blasting operation is shown in Figure 3.2. Blasting is not similar to any other fugitive dust source, so development of an emission factor cannot be accomplished by comparison or extrapolation of data from other operations.

This operation is an obvious dust source wherever it occurs. While its appearance indicates that it is a major

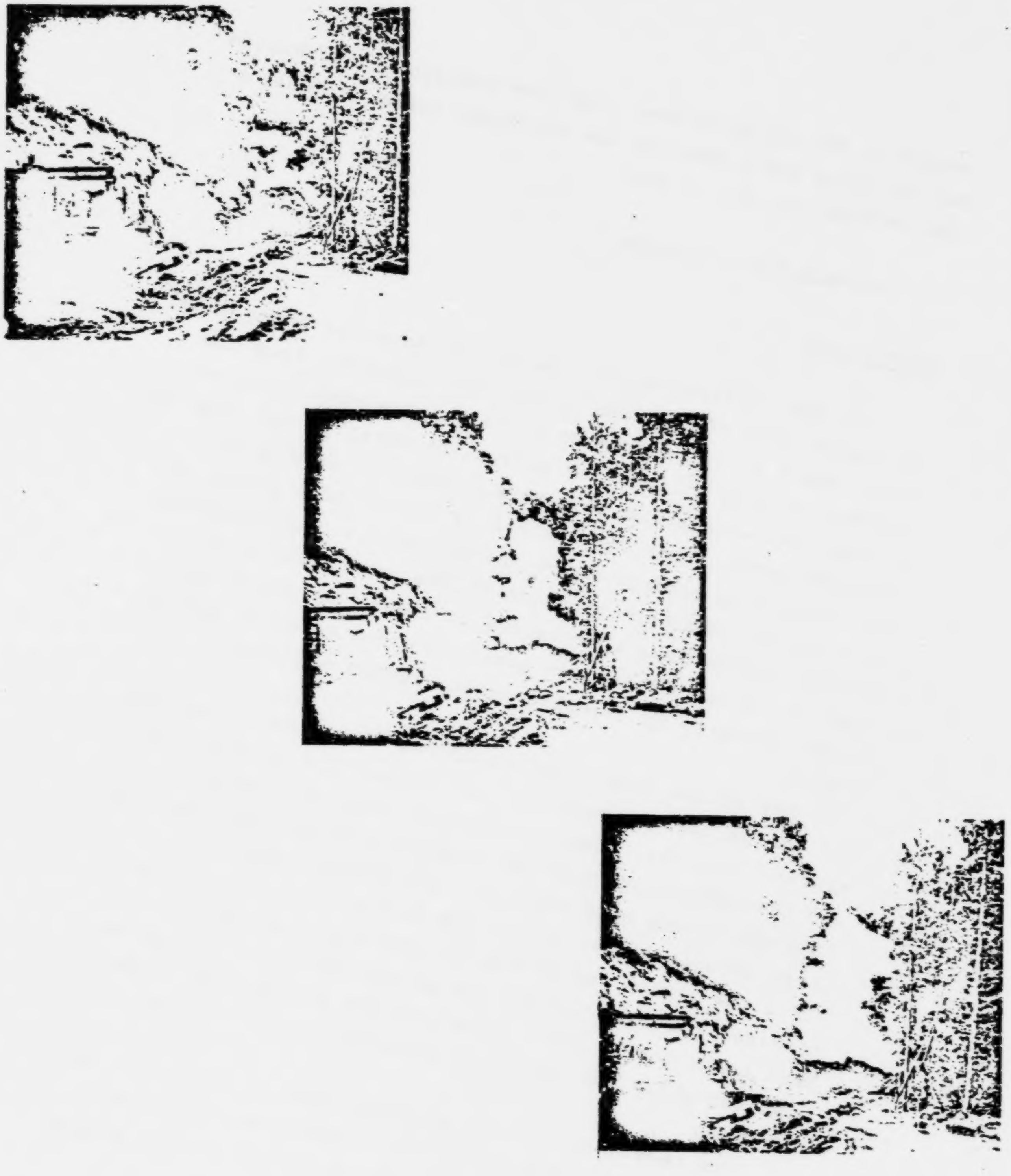


Figure 3.2. Blasting.

source of mining emissions, its time-averaged contribution may be quite small because the emissions occur for only a few seconds per day or week.

3.3 SHOVELS/TRUCK LOADING

Description

In most surface mines, the ore or material being mined is loaded onto off-highway trucks for transport from the point where it is removed to a central transfer location or processing area at the mine site. The material can also be transported within the mine in a mechanical or hydraulic conveyor system, but this method is rarely used except in phosphate rock mining, where the deposit is usually pumped as a slurry through a pipeline to the processing area. Another seldom used alternative to shovel and truck operation is the mobile storage bin into which material can be loaded directly by dragline, then crushed and loaded into trucks.

Any of the excavation equipment described in Section 3.1 can be used to excavate the deposit and load it onto trucks. However, electric powered, crawler-mounted shovels are most often employed for this purpose because they can load the trucks more quickly. The shovel breaks the fractured deposit loose, scoops the bucket full of material, lifts the bucket and swings it over the truck bed, and releases the load through the hinged bottom of the bucket. When the truck is full, it drives off and another moves into position while the shovel is scooping another bucket of material.

The newer haul trucks at mines usually have load capacities of 100 to 200 tons and are diesel-electric powered. The trucks may be either end dumping or the gondola-shaped bottom dumping, depending on the configuration of the tipple, or dumping area. The same trucks may also carry low grade ore or unmarketable material in the deposit to a separate dump area for disposal. The loading operation and fugitive dust potential for scooping and loading this waste material is identical to that for the material being mined.

A small front-end loader may be assigned to the area being worked by the shovel to remove spilled material that could cause damage to truck tires and to move materials that cannot be easily reached by the less maneuverable shovel. For irregular deposits and smaller mines, a front-end loader may be used instead of an electric powered shovel.

The area where the shovel is working is normally freshly exposed, so the material has almost the same moisture content as the unexposed deposit. However, the position where the trucks are loaded may dry rapidly as a result of the traffic movement. It is difficult for watering trucks or other control equipment to gain access to truck loading areas because of the danger of driving near the mining equipment or haul trucks (which have poor close range visibility) and because the shovel, the deposit, and the power line for the shovel often block access from all but one direction.

Emission Estimate

Dust is generated at many points in the truck loading operation, but mainly by the scooping of loose material by the shovel, dumping from the shovel bucket into the truck bed, and movement of trucks into position to be loaded. Dust generation from truck loading is shown in Figure 3.3. Several emission estimates have been made for the entire operation. Midwest Research Institute sampled the loading of crushed rock by front-end loaders and determined an

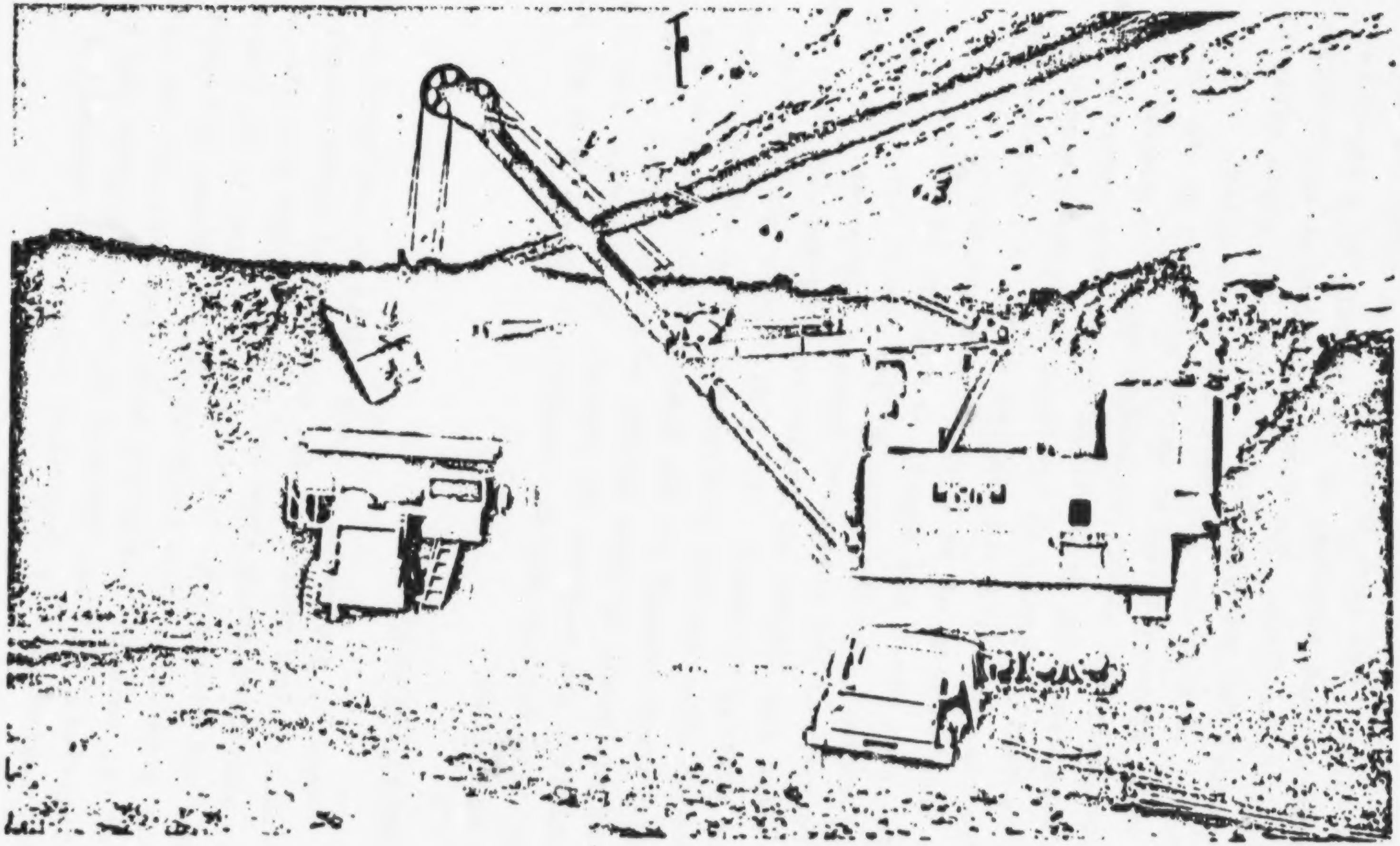


Figure 3.3. Truck loading.

Source: Draft EIS, Eastern Powder River Coal Basin, 1974, p I-74.

average emission rate of 0.05 lb/ton of rock.[12] This emission factor was also applied by PEDCo to loading of copper ore by shovels as the differences in the two operations were thought to offset one another:[13]

- the shovel must break the fractured rock loose instead of just scooping it out, resulting in higher emissions than for loading of aggregate;
- the shovel is not as maneuverable as a front-end loader and therefore drops the rock a greater distance into the truck;
- the crushed rock tested was very dry and contained a substantial amount of fines, in comparison with moderate moisture content and few fines for the shovel operation; and
- the crushed rock loading was exposed to higher wind speed conditions than the copper ore loading.

The effect of the shovel's larger bucket size on emission rate could not be determined.

The PEDCo emission factor estimate for loading lignite coal in North Dakota is 0.02 lb/ton loaded. This lower estimated emission rate was based on comparison with loading of crushed rock, considering the higher moisture content and fewer fines in the lignite. The lower value also appears reasonable in comparison with emissions from other operations at the lignite mine, such as truck dumping and grader operation.

The ERT air quality analysis for Colorado coal mines cited in Section 3.1 proposed the same emission factor for coal removal and loading as for overburden removal, 0.048

/ton. This value is almost the same as those developed for crushed rock and copper ore, and may be a function of lower moisture content in the coal beds in northwest Colorado than in North Dakota lignite.

Monsanto Research's sampling at a crushed granite plant indicated that loading onto haul trucks produced negligible emissions,[14] reportedly because of the large aggregate size, i.e., the absence of fine granite dust.

The Hittman report included an emission factor of 0.04 percent due to "windage losses" in truck hauling at coal mines.[9] It was indicated that most of these emissions occurred at the two ends of the hauling trip--loading and dumping--and that most of the weight loss was probably as airborne particulate. However, much of the airborne particulate could still be due to settleable material. If it is assumed that half of the total "windage losses" of 0.8 lb/ton (0.04 percent) occur during loading and that 25 percent of this material remains suspended, the emission estimate for truck loading would be 0.10 lb/ton. This is higher than the other estimates, but certainly close enough to confirm the relative magnitude of these other values.

Independent emission estimates for the truck loading operation cover a fairly wide range, possibly indicative of the many variables involved in this operation. The most important of these variables are the moisture content and amount of fines in the material being loaded, the number and types of equipment working in the loading area, and climatic conditions at the mine.

3.4 HAUL ROADS

Description

Haul roads, mostly temporary unpaved roads between the active mining areas, tipple, waste disposal areas, and equipment service areas, are common to all surface mines. In a typical mine, these roads constitute about 10 percent of the total area directly disturbed by the mining.[16] Because of the size of the trucks and crawler-mounted equipment that use these roads, they are normally constructed at least 40 ft wide. In mines opened in recent years, particularly those in the West that use 100 to 200 ton capacity trucks, the roads may be as wide as 100 ft.

Some of the haul roads at the mine lead from bench level at the bottom of the deposit to undisturbed surface elevations, which may be 200 to 300 ft higher. Therefore, these haul roads either have a steep grade or follow a circuitous route to the higher elevation. In areas where contour mining is practiced and lighter equipment is used, the roads generally exhibit poor alignment and drainage, low durability, and marginal maintenance. Where area mining is practiced with its attendant heavy equipment, roads are necessarily better engineered.

Road surfaces vary according to the terrain, type of operation and size of equipment used. Road surfaces may be graveled but more commonly they are just graded. In areas of flat open terrain, the roads are graded with berms thrown up at the road edges from excess material generated during grading or maintenance. In Eastern states, where mine operations are located in hilly or forested terrain, the use of berms is often prohibited or discouraged because of its adverse drainage effect.

Haul roads are normally cleared of spilled material and regraded frequently while in use. Heavy equipment tends to rut and compact the surface. Continuous maintenance of haul roads for the heavy equipment makes higher speeds possible and provides greater usage time of the roads. Generally, the haul roads are built and maintained as cheaply as possible while still not slowing down production from the mine. At any given time, only a portion of the roads at the mine site will be active, but the abandoned roads are left as is for possible reuse when the active mining area moves again. In the interim period, they serve a definite purpose in providing good access throughout the mine.

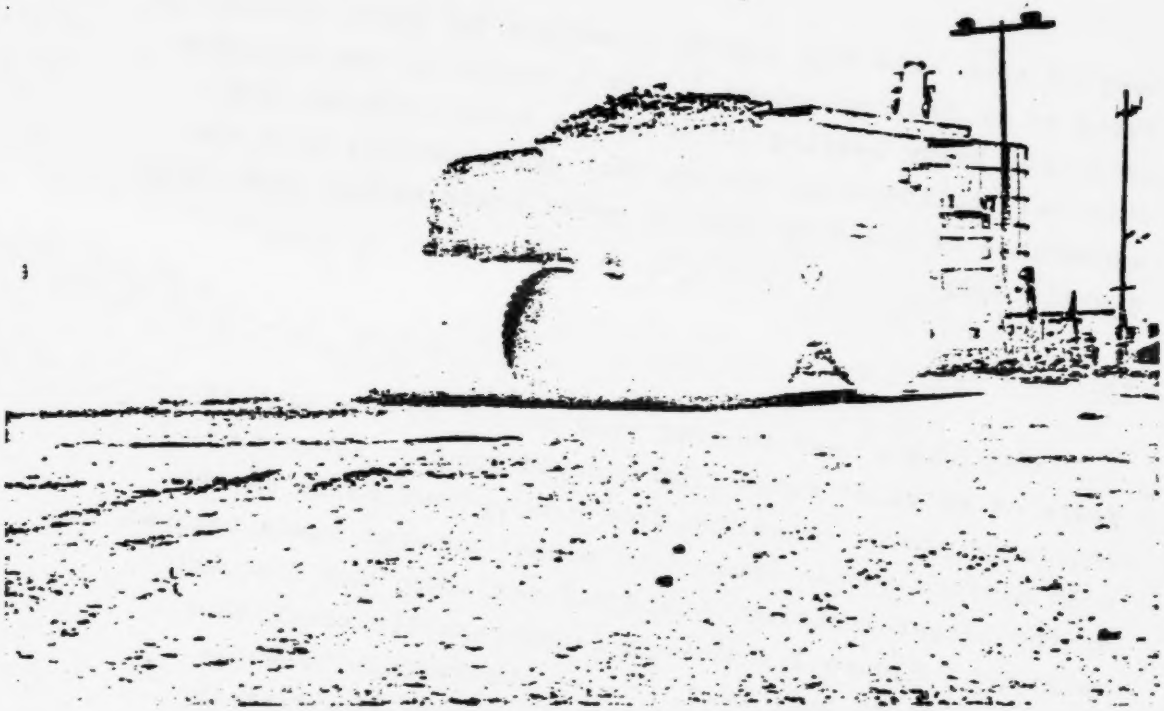
In addition to the haul trucks, other vehicles use the haul roads regularly--water trucks, fuel and service trucks, pickup trucks, motor graders, bulldozers, and explosives trucks. The vehicle miles traveled (VMT) per day on haul roads can be estimated from the numbers of each type of vehicle in operation at a mine and their respective driving patterns (e.g., round trip distance from loading area to tipple and number of loads per shift per truck). Alternatively, the VMT can be estimated from total gasoline and diesel fuel usage and average fuel consumption rates for the different vehicles.

Haul roads at mines are routinely watered for dust suppression during all periods when water on the road surface does not create a safety hazard (generally when temperatures are above freezing). The water is usually applied by large tank trucks equipped with a pump and directional nozzles which spray the road surface and adjacent shoulders and berms. Fixed pipeline spray systems have also been used on main haul roads that are relatively permanent. Various chemicals may be added to the water or applied separately to the road surface to improve binding and reduce dusting. Over 100 dust suppressant materials are now marketed, and many of them have been proven effective for short periods in tests on mining haul roads.[17] As a result of the frequent watering, heavy bearing loads on the road surfaces, and chemical applications, mining haul roads usually have the appearance of oiled or crudely paved roads rather than rural gravel roads.

Emission Estimate

There have been several studies during the past few years of emission rates from unpaved roads. However, as indicated above, emissions from mining haul roads may be much different than those from normal unpaved roads because of the larger vehicles, compacted surfaces, and frequent watering. Figure 3.4 shows a large-capacity truck on a well-controlled haul road. Close observation of well-controlled haul roads reveals that much of the dust is generated near the edges of the roads, where the surface is composed of looser material, and in areas where the surface has dried. Also, haul roads have fugitive dust emissions that result from movement other than traffic--road construction and repair, loss of fines from the open bed trucks during transit, and wind erosion on abandoned and seldom used roads. Vehicle exhaust contains particulate emissions, but it is not considered to be fugitive dust and is therefore not included in the emission estimates.

There have been at least three different emission estimates made specifically for traffic on unpaved haul roads. The first of these was by PEDCo. It was developed from EPA's published emission factor for unpaved roads:[18]



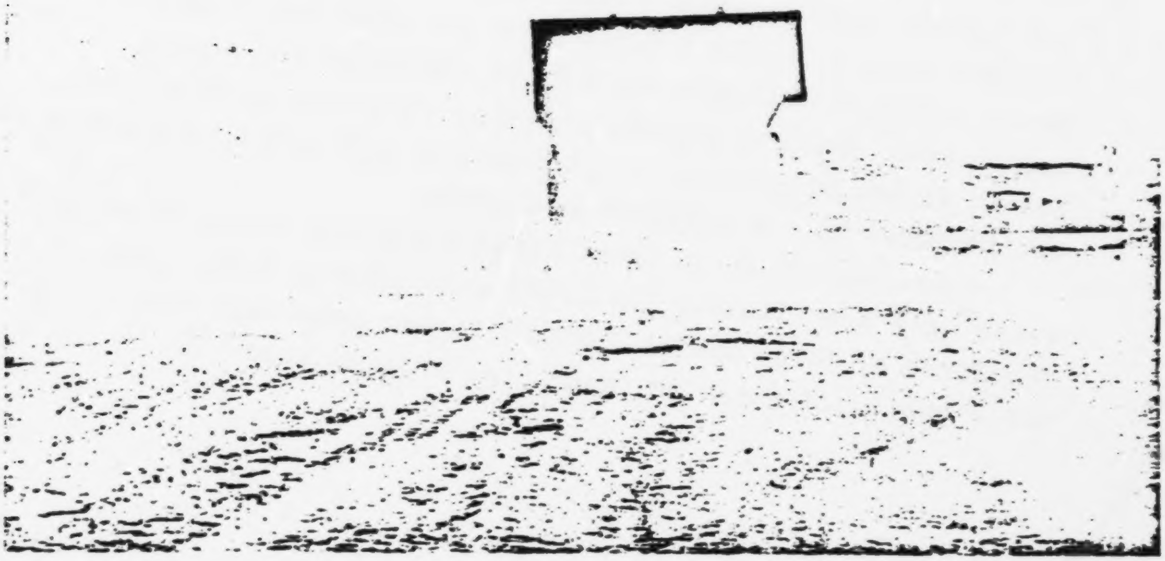


Figure 3.4. Haul roads.

$$EF = (0.60)(0.81)(s)(S/30)(1-W/365) \qquad \text{(eq.1)}$$

where EF = emission factor, lb/VMT

0.6 = average fraction of emitted particulate in the suspended particulate size range (less than 30 μ diameter)

s = silt content, percent

S = average vehicle speed, mph

W = days with 0.01 inch or more of precipitation or reported snow cover

This emission factor was modified to account for the much larger surface area of the road in contact with the truck tires. It was assumed that the relative emission rates for off-highway trucks, even though they have only four tires, would be two and one-half times as great as for light duty vehicles, based on the comparative widths of tire faces. Other input data used to calculate the emission factors for two different mining operations are summarized below:

Parameter	For open pit copper mine	For lignite surface mine
Average vehicle speed, mph	15	20
Days/yr with no rain or snow cover	274	166
Emission reduction due to watering and chemicals, percent	80	50
Emission factors, lb/annual VMT		
Haul trucks	1.1	2.2
Pickup trucks	0.4	0.9

In addition, an uncontrolled emission factor of 32 lb/hr was proposed for grader operations in these PEDCo studies, and the same control efficiencies were assumed for the graders working on the haul roads as for the truck traffic. Windage losses in transit were thought to be negligible in comparison with emissions from the road surfaces in these two instances, but for some materials the emissions from the moving trucks could be significant. Wind erosion emissions from the haul roads were assumed to be indistinguishable from wind erosion of other exposed areas at the mines and were therefore considered in another source category.

Monsanto Research's study of a granite quarry showed emission rates from "vehicular movement on unpaved roads" of 0.048 lb/ton of material processed, or about 2.4 lb for each round trip to the crusher, assuming 50 ton capacity trucks and only haul truck traffic on the roads. A conscientious haul-road watering program was reportedly being implemented at the mine during the test program. Since the dimensions of the quarry and hauling frequency were not described, it is not possible to compare this value directly with the other available emission factors. However, it appears to be somewhat lower.

ERT used a base emission factor of 3.7 lb/VMT (obtained from an early study of fugitive dust emission sources)[17] for both haul trucks and light duty vehicles at surface mines in northwestern Colorado. This factor was then reduced by multiplying by a climatic correction of 0.44, the fraction of days when the surface was not wet or frozen, and a control factor of 0.50 to account for watering of the roads on dry days. The resulting net emission factor was 0.8 lb/VMT for total annual travel at the mine. This value is near the weighted average of emission rates for the copper mine and employed the same rationale as the PEDCo study in applying correction factors to account for differences between emission rates from normal unpaved roads and mining haul roads.

The available emission factors for this mining operation are in fairly close agreement. Using any of these values, haul roads are shown to be a major fugitive dust source at all surface mines, even with the relatively high control efficiencies obtained with frequent watering and use of chemical dust suppressants. The calculation procedures used to derive the factors indicate that variables which affect emissions from this operation most are vehicle speed, estimated control efficiencies, and climatic conditions at the mine.

3.5 TRUCK DUMPING

Description

Truck dumping is the simplest operation at the mine to describe--it involves only the dumping of the mined material from the truck into a tipple or receiving hopper for the primary crusher. The same operation may also occur at the edge of a spoils slope if the truck is dumping waste material or overburden. While the operation is quite simple, it has been identified as a significant fugitive dust source at many different mines,[13,19] as shown in Figure 3.5.

Emission Estimate

Dust is generated as the material tumbles from the truck bed and strikes the ground or side of the hopper. Three different estimates of the emission rate from this operation were located. Midwest Research Institute, in a sampling study of aggregate handling operations, estimated that dumping of crushed rock or gravel onto storage piles accounted for about 12 percent of the total emissions of 0.33 lb/ton from handling, or 0.04 lb/ton. The truck dumping operation was not sampled in isolation from the other

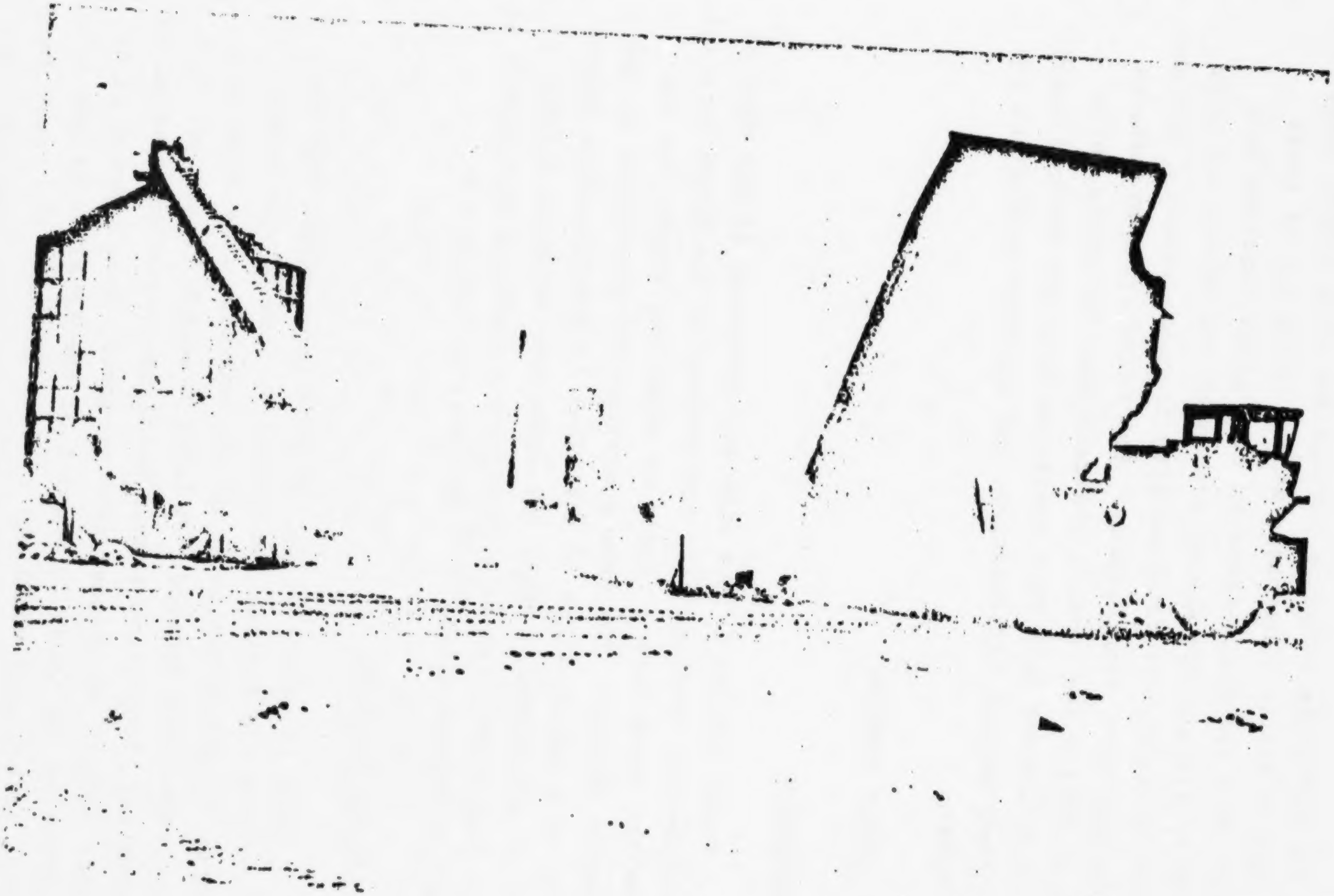


Figure 3.5. Truck dumping.

Source: Draft EIS, Eastern Powder River Coal Basin, 1974, p I-75.

handling operations and the estimate of 12 percent was partially subjective. This emission factor for dumping of aggregate onto storage piles was recently published in Supplement 5 of EPA's Compilation of Air Pollutant Emission Factors.[18]

Monsanto Research determined an emission rate of 0.00034 lb/ton for truck unloading at the hopper of a primary crusher.[14] The material being handled was quarried granite with very little fine material present.

For two separate studies, PEDCo used an emission factor of 0.02 lb/ton for truck dumping. This value was derived by taking half the published EPA emission factor for dumping of aggregate because of the much larger size of the broken ore and coal being handled and its higher moisture content. The 50 percent reduction was based on the estimated control efficiency of watering,[17] which is probably comparable to the effects of higher moisture content and larger material size.

Intuitively, it seems that emissions from truck dumping should be less than for the truck loading operation because dumping does not include the activity of the shovel or front-end loader in loosening and scooping the deposit. In comparison with the values presented in Section 3.3 for emissions from truck loading, the MRI and PEDCo factors for truck dumping appear to be quite reasonable. However, as with most of the mining operations, there may be a wide range of emission rates for mines of different minerals or in different climates.

3.6 CRUSHING

Description

The crushing operation is a fugitive dust source at both underground and surface mines. The material is charged to the primary crusher by means of a receiving hopper. At large mines, there may be more than one hopper or dumping bin serving separate primary crushers placed in parallel. Primary crushers are jaw crushers, set to act upon rocks larger than about six inches and to pass smaller sizes. Depending on the ultimate size requirements of the product, the material from the primary crusher may be screened with the undersize going directly to the screening plant and the oversize to secondary crushing, or all material from primary crushing may be routed to the secondary crusher. The secondary crushers are of the cone or gyratory type.

As the material is crushed, much more surface area is created. If the incoming material has a high internal moisture content (such as lignite coal), the new surfaces will be moist and nondusting. However, if the material has a low internal moisture content, the crushing greatly increases the potential for airborne dust generation. The new surfaces tend to dry out as the material continues through the process on conveyor belts and through the secondary crushers and screens. As the rock or coal becomes more finely ground and drier, the in-process dust releases become greater.

One method of suppressing the in-process dust is by adding water to keep the material moist at all stages of processing. If the use of water can be tolerated, it is usually sprayed at the crusher locations and shaker screens. The addition of water may cause blinding of the finest size screens, thereby reducing their capacity.

The crushing/screening operation is either fully enclosed or the dust emission points are hooded, with a local exhaust system, control device, and stack. This is the only operation at the mines that would not be strictly defined as a fugitive dust source, since the emissions are confined and emitted at a single point (as shown in Figure

3.6). However, most crushing operations still have some fugitive dust losses that escape the hooding system at points such as the crusher discharges and conveyor transfer points. At rock quarries, most of the crushers are portable, are not well enclosed, and therefore usually have particularly high fugitive dust emissions. One emission estimate for coal preparation assumed that half the dust generated went through a collection system to controls and half escaped.[8]

Emission Estimate

For coal crushing, EPA's published compilation of emission factors does not include a quantitative estimate, but states that "the crushing, screening, or sizing of coal are minor sources of dust."[20] The writeup on coal crushing also indicates that 95 percent control can be achieved by use of water sprays and 99+ percent control is possible with sprays followed by mechanical dust collectors. The Hittman report[9] also states that dust emissions from coal preparation plants are negligible.

Based on some data from coal processing for coke production, PEDCo estimated[21] that the uncontrolled emission rates for the three major emission points in the operation would be:

Primary crushing = 0.02 lb/ton
Secondary crushing = 0.06 lb/ton
Secondary screening = 0.10 lb/ton

In combination with the estimated control efficiencies cited above, these values appear to substantiate the non-quantitative evaluations that coal crushing is only a minor dust-producing source.

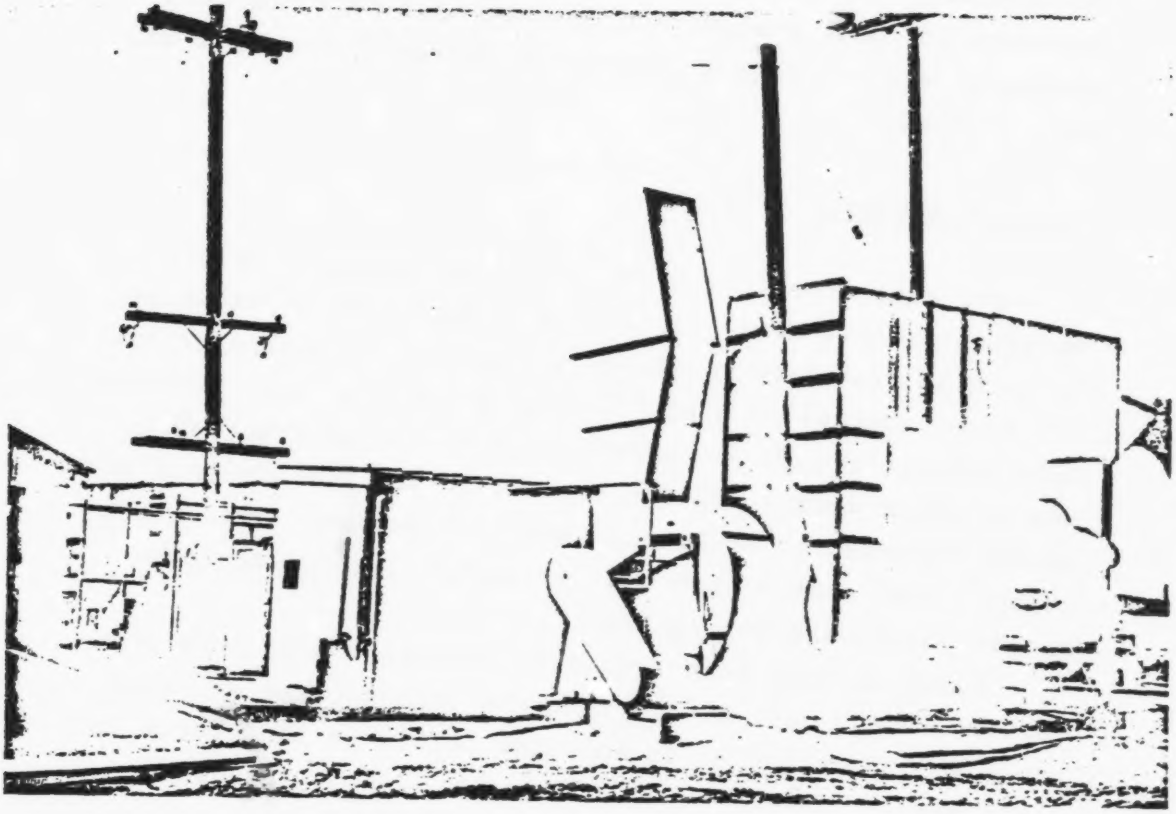


Figure 3.6. Crushing.

In contrast, the current EPA emission factors for rock crushing are quite high, as shown below:[20]

Primary crushing = 0.5 lb/ton total
= 0.1 lb/ton suspended particulate

Secondary crushing and screening = 1.5 lb/ton total
= 0.6 lb/ton suspended particulate

It has been noted that even the lower of the two sets of emission factors often overestimates annual emissions from rock quarries in regional emission inventories, indicating that these factors are most applicable to uncontrolled portable crushers or must be combined with very high control efficiencies to produce reasonable values. It cannot be determined from the source descriptions whether the EPA emission factors include just stack emissions or both stack emissions and fugitive dust losses.

Crushing operations at a granite quarry have been sampled by Monsanto Research.[14] Their results, which include both stack emissions and fugitive dust, are more consistent with expected emission rates than the EPA values:

Primary crushing = negligible
Secondary crushing = 0.018 lb/ton
Secondary screening = 0.026 lb/ton

3.7 TRANSFER AND CONVEYING

Description

Although conveyor systems may be used to transport material from the active mining area to the processing area or to deliver the processed material to the consumer, conveying is most often found within the processing area--moving the crushed material to storage, a cleaning process, or the train loading station. This operation also includes the loading of train cars and other transfer of the material, except for conveyors within the crushing or storage operations which are considered to be integral to these operations. Because of the large tonnages that must be moved in mining, most of the transport systems are belt conveyors rather than screw, vibrating, or continuous-flow conveyors.

Generally, conveyor runs between processes are less than 1,000 ft. The average length of the few haulage conveyors between pits and crushers is about 2,100 ft,[22] and off-site delivery conveyors of up to 12 mi have been built for coal.

Loss of material from the conveyors is primarily at the feeding, transfer, and discharge points and occurs due to spillage or windage. A conveyor belt is shown in Figure 3.7. The total weight loss in transit is certainly greater than the fugitive dust emissions from this operation since much of the spillage is deposited along the conveyor and some of the windblown material is in the settleable size range.

Excessive moisture in the material or air currents can create discharge problems on belt conveyors. Therefore, most are enclosed, and in some cases the transfer points may be hooded and vented to a dust collector. Both the enclosure and the hooding greatly reduce fugitive dust emissions from this operation.

Emission Estimate

Conveying is one of the most variable mining operations with respect to fugitive dust emission rates. In many

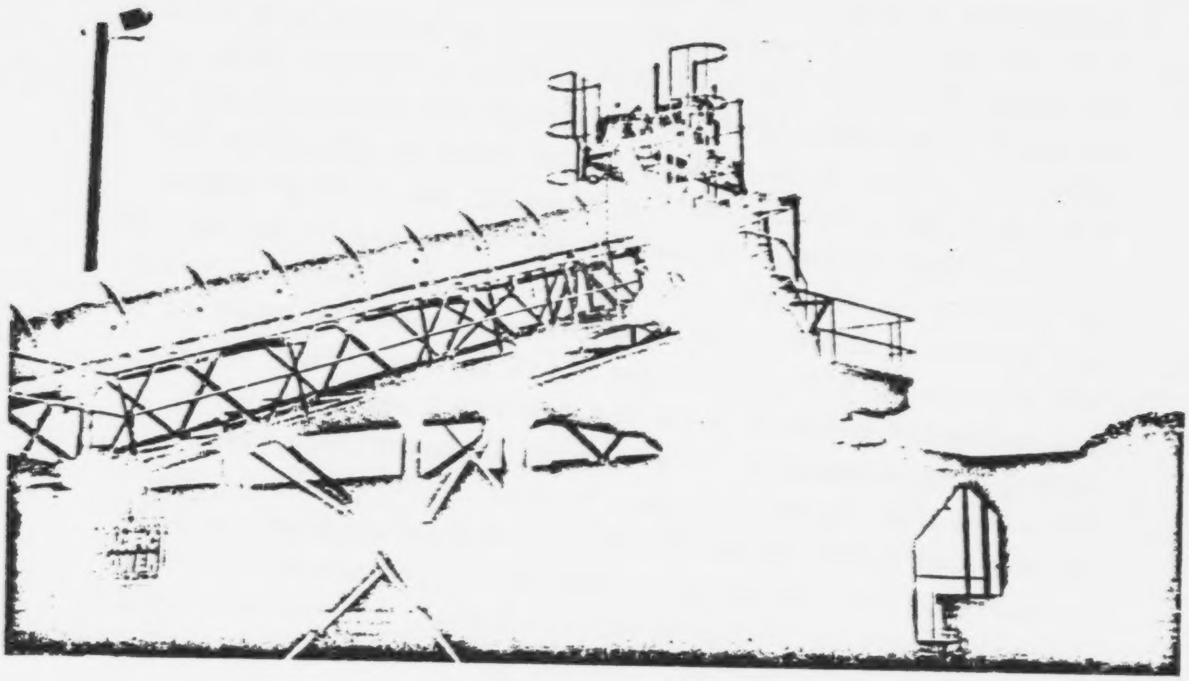


Figure 3.7. Transfer and conveying.

mines, there are no belt conveyors or similar transfer processes; the material is moved by truck to the tipple and loaded directly onto trains. At other mines, extensive networks of unenclosed conveyors are used, such as with bucket wheel excavators. Also, the emissions from conveying different materials vary greatly, depending in part on size distribution and moisture content.

ERT proposed a single emission factor for the combined processing sources at coal mines in northwestern Colorado--0.44 lb/ton (0.044 percent of material processed with half of these emissions fugitive dust). The processing sources at these mines were identified as transfer and conveying, crushing, and storage. Since other emission estimates are available specifically for the crushing and storage operations at coal mines, a value for conveying can be determined by subtraction from the overall ERT emission factor. Using the higher of alternative emission estimates for crushing and storage of 0.18 lb/ton and 0.054 lb/ton, respectively, the indicated emission rate for conveying would be 0.20 lb/ton. This seems to be excessive in comparison with estimates for conveying other material, and may be an indication that other unidentified particulate sources are also included in the ERT emission factor for the processing area. The value of 0.20 lb/ton does not account for the relatively high control efficiencies, usually at least 90 percent, associated with enclosed transfer and conveying systems.

The Hittman report stated that coal conveyor systems "are either covered or operated at such a speed that dusting does not occur to any great extent." Also, it was pointed out that only a small proportion of coal transport is done by this method. However, the same report used a value of 0.04 percent, or 0.8 lb/ton, loss through spillage at conveyor transfer points. Even if only a few percent of the spillage losses are in the form of dust, emissions from coal conveying would be comparable to those from coal storage piles.

Monsanto Research sampled conveying operations at a granite quarry and determined that fugitive dust emissions from conveying crushed granite are also negligible.[14] The report did not mention whether the conveyor was enclosed.

Monsanto Research also sampled storage and handling operations for phosphate rock and derived an emission factor of 0.35 lb/ton for the combined operations.[23] With a stated emission factor of 0.20 lb/ton for storage, the indicated emission rate for handling (conveying and loading onto railroad cars after drying) is 0.15 lb/ton. It is assumed that all the handling following drying is in enclosed, controlled systems.

PEDCo developed an emission factor for transfer and loading of dry phosphate rock which agrees well with Monsanto Research's factor. The PEDCo emission estimate of 1.5 lb/ton uncontrolled, with average control efficiencies of 90 to 95 percent, was developed from source test data and company estimates provided by six phosphate industry plants in Flordia.

3.8 CLEANING

Description

Cleaning or beneficiation of the ore improves the quality of the mined material by separating undesired components at the mine site. This operation greatly reduces the amount of material which must be shipped to the processing plant and also decreases solids handling and disposal problems in all subsequent refining steps (or the combustion process in the case of coal).

By far the most common method of beneficiation is froth flotation, where a slurry of the crushed ore is subjected to aeration in the presence of reagents which selectively separate the mineral being mined from other material in the deposit. In order for the flotation process to work properly, the ore must be crushed or ground small enough to liberate the mineral being extracted. Metallic ores are generally ground finer than 48 mesh and coal and most non-metallic ores should be 20 mesh or finer.

In flotation machines, the ore is suspended in water at a loading of 15 to 35 percent solids by means of air or mechanical agitation. Surfaces of the mineral particles are treated with chemicals called promoters or collectors which make the particles aerotropic and hydrophobic. With continued aeration or agitation and the addition of a frother, a layer of foam forms at the water surface. The treated mineral particles become attached to air bubbles, rise to the surface, and are skimmed off. Untreated components collect in the bottom area and are drained off as underflow. The valuable concentrate from froth flotation may be either the froth product or the underflow product. Metallic sulfides of copper, lead, zinc, nickel, mercury, and molybdenum collect in the froth.

The initial low-grade concentrate may be processed through a second "cleaner" flotation cell to remove additional extraneous material. The tailings from the cleaner cells are recirculated through the system or concentrated separately in additional cells. Regrinding of these middlings is necessary in many ores. The tailings or waste material from the flotation machine are discarded in slurry form for easier transport. The final concentrate is dewatered in thickeners and filters prior to shipment.

Well over 90 percent of non-ferrous metallic ores are concentrated by froth flotation prior to smelting.[24] Most of the phosphate rock fines in Florida are recovered by flotation. About 70 percent of the coal from underground mines and 30 percent from surface mines are subjected to some type of mechanical cleaning--by jigs, concentrating tables, dense media, or flotation. Of the coal that is cleaned, about 20 percent is thermally dried.[9]

Emission Estimate

Much of the cleaning operation is performed in water, and even after the concentrate or cleaned material is dewatered it is still wet and non-dusting. Only if an unusual cleaning process such as magnetic separation, dry tabling, mechanical classification, or air blowing is used does this operation have any potential for fugitive dust generation.

Thermal dryers at coal cleaning plants are significant particulate air pollution sources, but they would not be categorized as fugitive dust sources. Emission estimates for the common types of coal dryers are presented in EPA's Compilation of Air Pollutant Emission Factors, along with estimated efficiencies of various control devices:

Type dryer	Uncontrolled emissions, lb/ton
Fluidized bed	20
Flash	16
Multilouvered	25

Cleaning has been included as a mining operation with potential for fugitive dust emissions mainly for completeness. At most mines, there are no emissions associated with this operation. No emission factors were found in the literature for sources other than the thermal coal dryers.

3.9 STORAGE

Description

This operation involves any open storage pile of the mined material that is located at the mine site, either prior to or after some initial processing. The storage piles may be short-term with a high turnover to accommodate irregular daily or weekly throughput rates for different sequential processes, or may provide a long-term reserve for emergency supplies or to meet cyclical seasonal demands. Frequently, however, there is no stockpiling of material at the mine site because of the extra handling required.

The material is usually placed on the storage pile by means of a tipple arrangement or a conveyor, as shown in Figure 3.8. Equipment such as bulldozers, front-end loaders, and small shovels may be used to move material within the storage area or position it for loading out of storage.

The emission estimates presented in this section are, with the exception of dry phosphate rock, for unenclosed storage piles. In cold or wet climates, the material may be placed in storage silos from which it can be loaded directly into unit trains. Silos vary in diameter, height, and number depending on mine production and train scheduling. For coal, silos about 150 ft high and 70 ft in diameter with a capacity of approximately 11,000 tons are typical. The only fugitive dust losses associated with silos or other enclosed storage facilities are from transfer and conveying, which are considered as a separate operation (see Section 3.7).

Also, the storage operation as defined herein does not include topsoil or waste material storage. These are also parts of other operations, reclamation and waste disposal.

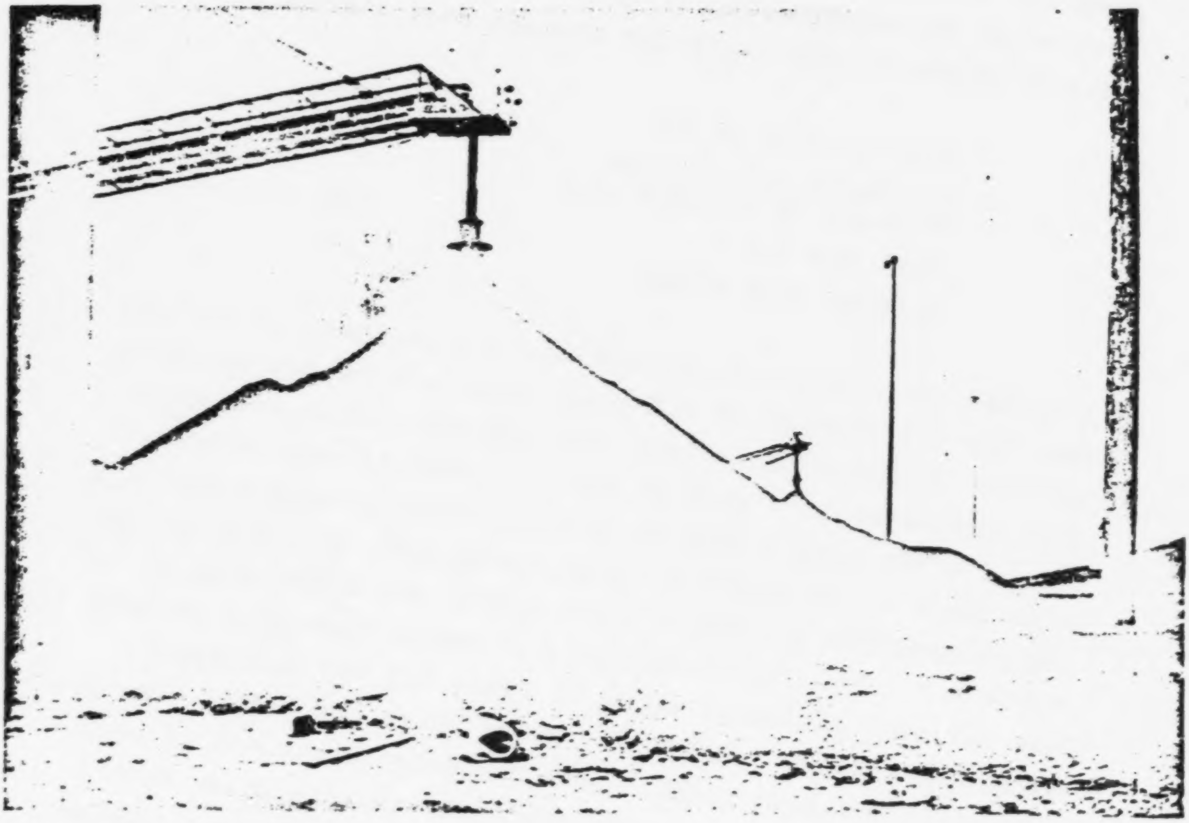


Figure 3.8. Storage.

Emission Estimate

Fugitive dust emissions from the storage area occur as a result of several activities. According to sampling data compiled and evaluated by Midwest Research Institute,[12] the four major emission-producing activities and their approximate relative contributions for crushed rock storage are:

Loading onto piles	12%
Equipment and vehicle movement in storage area	40%
Wind erosion	33%
Loadout from piles	15%

Although the percentage contributions from these activities may vary for storage of different materials or for specific storage area configurations, the same activities are probably the major dust sources for all types of open storage.

The MRI study produced emission factors applicable to a wide range of aggregate storage operations, possibly including crushed ore storage. These values are summarized in Table 3.2. MRI also developed a climatic factor to correct the emission estimates shown in Table 3.2 for different geographic areas: $(100/PE)^2$, where PE is the annual precipitation-evaporation index.[a] EPA has adopted the MRI emission factor based on tonnage throughput for storage piles with a normal mix of activity for publication in the latest supplement to their *Compilation of Air Pollutant Emission Factors*: $0.33/(PE/100)^2$ lb/ton.

The Hittman report contained emission estimates for aboveground coal storage for only two coal mining areas, the

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[a] A national map showing PE values for all parts of the country can be found on p. 99 of EPA's *Compilation of Air Pollutant Emission Factors, Supplement No. 5*.

Table 3.2. EMISSION FACTORS FOR CRUSHED ROCK STORAGE PILES

Activity rating	Emission factor lb/acre of storage/day	lb/ton placed in storage
Active[a]	13.2	0.42
Inactive (wind erosion only)	3.5	0.11
Normal mix[b]	10.4	0.33

[a] Eight to 12 hours of activity per 24-hr period.

[b] Five active days per week.

Source: Development of Emission Factors for Fugitive Dust Sources, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina, Publication Number EPA 450/3-74-037, June 1974.

Northwest (Powder River Basin) and the Southwest (Four Corners area). In the Northwest, emissions were assumed to be "minimal" because of the rapid turnover of coal in storage. The emission factor for coal storage in the Southwest was 0.0235 lb/ton, based on the average wind erosion rate for arid portions of the Great Plains, 428 lb/acre/yr. The coal at the single mine for which this estimate is applicable is stored in piles 90 ft wide, 800 ft long, and 30 ft high, containing about 30,000 tons of blended coal.

A coal storage pile was sampled for dust losses by Monsanto Research. On two separate runs, the coal pile produced emissions at rates of 0.009 and 0.016 lb/ton in the pile (static rate); these were converted to an annual emission rate of 0.054 lb/ton placed in storage by use of additional information on the storage throughput rate.[23] It was indicated that no loading or unloading took place in the storage area during either of the sampling periods.

Monsanto Research performed a similar sampling study for a phosphate rock storage pile and developed an average emission factor of 0.20 lb/ton of "wet" rock in open storage. The phosphate rock may be shipped wet to the chemical processing plant or it may be dried at the mine site. Because of the difficulty in handling the material after it has been dried, the trend is toward locating the driers and grinders at the chemical processing plant rather than at the mine. However, if the phosphate rock is dried on-site, then subsequent storage prior to shipment is a major fugitive dust source even though the dry phosphate rock must be stored in an enclosure. EPA's published emission factor for transfer and storage of dry rock is 2.0 lb/ton uncontrolled.[20] Source test data and company estimates of material loss collected by PEDCo for nine phosphate industry plants and mines in Florida indicated exactly the same average uncontrolled emission rate as the EPA value--2.0

lb/ton. Overall control efficiencies for storage buildings of 90 to 95 percent can be obtained by use of baghouses or scrubbers on vents and at transfer points within the building.

3.10 WASTE DISPOSAL

Description

In the mining and beneficiation of minerals and ores, large amounts of waste material are often generated. Examples of this waste material are low grade ore, slack coal, extraneous unmarketable rock of relatively large size, tailings, coal slurry, and mud slime. The waste may have the same handling characteristics as the raw material being mined and be disposed of in a fill such as shown in Figure 3.9 (e.g., a waste dump, leach pad, or gob pile), or the waste may be a slurry resulting from a cleaning or separation process which requires ponding.

The waste disposal operation is distinguished from overburden disposal because in most cases the area used for wastes is not reclaimed. The wastes are segregated and saved for future reprocessing, for byproduct recovery, or because they contain higher concentrations of toxic materials than the overburden. If the waste contains no potentially recoverable material and its toxic components do not create a leaching problem, it can be buried in the spoils for disposal.

Some of the activities associated with waste disposal are the same as for the mining of the ore, i.e., truck loading and dumping, haul road traffic, scraper operation, and grader operation. For purposes of estimating emissions by unit operation at the mine, movement of waste material should not be considered a distinct operation from the

Figure 3.9. Waste disposal.

Source: Environmental Protection in Surface Mining of Coal, U.S. Environmental Protection Agency, EPA 670/2-74-093, 1974, p 66.

primary activity (e.g., shovel/truck loading) unless it employs different equipment or occurs at a separate location such as the dump site.

The other aspect of waste disposal is the disposal site itself. If berms or dikes are constructed to contain a slurry waste, this activity is part of the waste disposal operation. Also, dried or inactive ponds of fine waste material, particularly copper tailings, are subject to severe wind erosion if they are not stabilized.

Waste disposal at coal mines creates another potential particulate air pollution source--spontaneous combustion of coal refuse piles and gob piles. However, burning coal waste piles are not fugitive dust sources, so they are not included within the scope of this report.

Emission Estimate

Excluding the disposal site, most of the fugitive dust-producing processes associated with waste disposal utilize the same equipment and activities as used in other mining operations. Therefore, their emissions can be estimated by comparison with these operations and application of appropriate emission factors.

The equipment activity which occurs at the disposal site, such as berm construction or grading of a leach pad, can generally be categorized as heavy earthwork construction. It may be appropriate to apply the emission factor for heavy construction from Supplement 5 of EPA's Compilation of Air Pollutant Emission Factors--1.2 ton per acre of active construction per month. However, this value is applicable only in arid Western areas in which the sampling to develop the emission factor was done.[12]

Emission estimates for dried tailings have been developed by PEDCo with use of the U.S. Department of Agriculture's wind erosion equation.[25] These estimates are a function of regional climatic conditions and assume no surface crusting:[17]

Climatic factor[a]	Emissions, ton/acre/yr
0.1	1.3
0.2	2.6
0.3	4.0
0.4	5.3
0.5	6.6
0.6	8.0
0.7	9.3
0.8	10.6
0.9	12.0
1.0	13.3
1.2	16.0

If complete crusting of the fine tailings material does occur, emissions are reduced by about 80 percent. Approximately the same emission reductions can be achieved by either chemical or vegetative stabilization of the tailings.

For most waste dumps and gob piles, there are emissions when the material is dumped onto the pile but probably no additional emissions from wind erosion due to a lack of small particles on the surface.

No other references were found which identified waste disposal operations as significant fugitive dust sources. With the exception of tailings pile erosion at certain types of mines, waste disposal is generally a very minor dust-producing operation.

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[a] See Figure 3.11 for climatic factors for all parts of the country.

3.11 LAND RECLAMATION

Description

All surface mining causes considerable alteration of the land on which it occurs and a certain amount of the surrounding area as well. Experience has shown that the most successful land reclamation results where programs are preplanned by the mine operators and become a concurrent part of the daily operation of the mine.[16] Segregation of the various strata in overburden removal is critical so that inferior spoil can be buried under clean fill, with topsoil returned to the surface to ensure successful revegetation.

This practice of continuous reclamation has already been introduced in Section 3.1 where the earth moving aspects of overburden removal were considered. In area strip mining, draglines fill mined strips with overburden removed from succeeding strips and topsoil is placed on top to prevent rehandling. In contour mining, the reclamation follows a pattern of grading and backfilling the bench between the highwall and the downslope. In this type of surface mining, the topsoil can be stockpiled for a limited time and replaced after the mining and grading have been completed. In contour mining by the block cut method, topsoil is removed and placed on graded areas in a single operation.

Success in reclaiming mined land is determined to a large extent by geographic location and climatic conditions. Each location has its own inherent problems to be dealt with if an area is to be returned to the original topography. In contour mining operations in the East, careful practices of grading and backfilling can return natural drainage patterns and contour to the land. Use of trees alone to revegetate these areas was found to be unsatisfactory, due to the length of time required for the trees to establish themselves and the loss of soil by erosion in the interim. Presently, herbaceous species are preferred to stabilize the land rapidly and plant covers suitable to the area are selected to control erosion, siltation, dust, and acid formation. In addition, seeding is no longer limited to the spring. Selecting species appropriate to the season when planting is needed and following with a perennial species in spring or fall provides optimum conditions for revegetation. In these Eastern states, as well as those Central states where contour mining is used, a period of two to three years is required to reach this condition.[9]

In Florida, area mining is practiced where phosphate rock is mined. Draglines strip overburden and fill the previous strip with this material in a single operation. The overburden is approximately 20 ft deep, with phosphate deposits of some 16 ft lying below. Land reclamation generally results in an area being filled and then graded to a level somewhat less than the original topography. Since the water table is comparatively close to the surface, this depression usually creates lakes but the process is completed and the area stabilized in one to two years.[26]

Area mine reclamation in Midwestern states poses the fewest reclamation problems. These lands can be returned to their original topography by spoil segregation, backfilling, and grading as deposits are removed. Compaction of the soil can be controlled with conventional equipment, and this ground preparation for revegetation is aided by a climate that provides sufficient annual precipitation.

Reclamation in the West is another matter. Here the seam thickness of deposits mined is much greater and the original elevation cannot be restored. If a pattern of continuous reclamation is used at these mines, the overburden is deposited by draglines parallel to the strip being mined; smaller draglines or bulldozers then level these deposits to reduce slopes. This returns the area to a topography that will meet proper conditions for land stability, drainage control, and maintenance of vegetation. A recently regraded area is shown in Figure 3.10. The process of reestablishment is estimated to require a minimum of five years. Due to the arid or semiarid climate, successful reclamation to native climax vegetation is questionable. The extreme climatic conditions, with a seasonal variation of -60 to 120° F and an annual precipitation for 75 percent of the area of less than 20 inches, create a soil of highly saline condition that contributes to a lack of adequate topsoil. Wind also erodes this unprotected soil, adding to the problems of reestablishment. It is possible to regrade this disturbed land but knowledge for successful seeding and procedures for revegetating the area are not yet adequate. In certain areas, such as the rimrock country in eastern Montana, it has been recommended that no mining be permitted in certain deposits. Here it would be impossible to restore the original drainage patterns and slopes.

The amount of soil loss due to wind erosion of the barren land prior to revegetation is a function of the surface soil type, roughness of the surface, windspeed, average surface moisture content, and unsheltered distance across the regraded area. Obviously, the total wind erosion losses from a reclaimed area are directly proportional to the length of time to establish protective vegetation on the surface. While these wind erosion losses are low level except during wind storms, they occur fairly continuously over the entire reclamation area and therefore may produce more fugitive dust than the mining and processing operations in some high wind erosion areas of the country.

Figure 3.10. Reclamation.

Emission Estimate

For continuous reclamation, the earth moving by the dragline and scrapers produces a large amount of fugitive dust, but these emissions are already included as part of the overburden removal operation. If the topsoil is stored and later redistributed or if a smaller dragline or bulldozer is used to grade the spoils area before applying the topsoil layer, emissions from these activities can be estimated with the same emission factors as for overburden removal.

All other emissions associated with the reclamation operation are due to wind erosion over the unreclaimed or partially reclaimed land. Emissions from wind erosion across cleared or unprotected soil surfaces have been estimated by use of the U.S. Department of Agriculture's wind erosion equation in several recent studies. The wind erosion equation was originally developed to estimate soil losses from cropland, but has been adapted[12] to predict the suspended particulate fraction of total soil losses and has been applied to evaluate exposed soil surfaces other than cropland.

The modified wind erosion equation is as follows:

$$E = a\ I\ K\ C\ L'\ V' \qquad \text{(eq.2)}$$

where E = emission factor, ton/acre/yr

a = portion of total wind erosion losses that would be measured as suspended particulate

I = soil erodibility, ton/acre/yr

K = surface roughness factor

C = climatic factor

L' = unsheltered field width factor

V' = vegetative cover factor

In this equation, K, C, L', and V' are all dimensionless.

Some recent work[27] has indicated that the variable "a," as well as I, is related to soil type. Values for "a" and I which might be appropriate to surface mined areas during or following regrading are summarized below:

Surface soil type	a	I, ton/acre/yr
Rocky, gravelly	0.025	38
Sandy	0.010	134
Fine	0.041	52
Clay loam	0.025	47

Values for K can vary between 0.5 and 1.0, with 0.5 denoting a surface with deep furrows and ridges, which protect against wind erosion, and 1.0 denoting a smooth erodible surface. Unless the surface of a regraded spoil area has been plowed or roughened, a K factor of 1.0 should be used in the wind erosion equation.

Climatic factors (C) for use in the equation have been determined for most parts of the country by USDA, as shown in Figure 3.11 (the values in the figure should be multiplied by 0.01). For exposed areas greater than about 2000 ft wide, the field width (L) no longer affects the emission rate and L' = 1.0. For smaller reclamation areas in irregular terrain where the field width is only about 1000 ft, the L' value is approximately 0.7. Since there is little or no vegetation on the recently regraded surfaces, V' in the equation is almost always 1.0.

By substituting the appropriate data into the wind erosion equation, the annual emission rate for any specific situation can be calculated. This estimated emission rate (E) is then multiplied by the number of barren acres at the mine during a particular year to determine total fugitive dust due to wind erosion. For a more detailed explanation

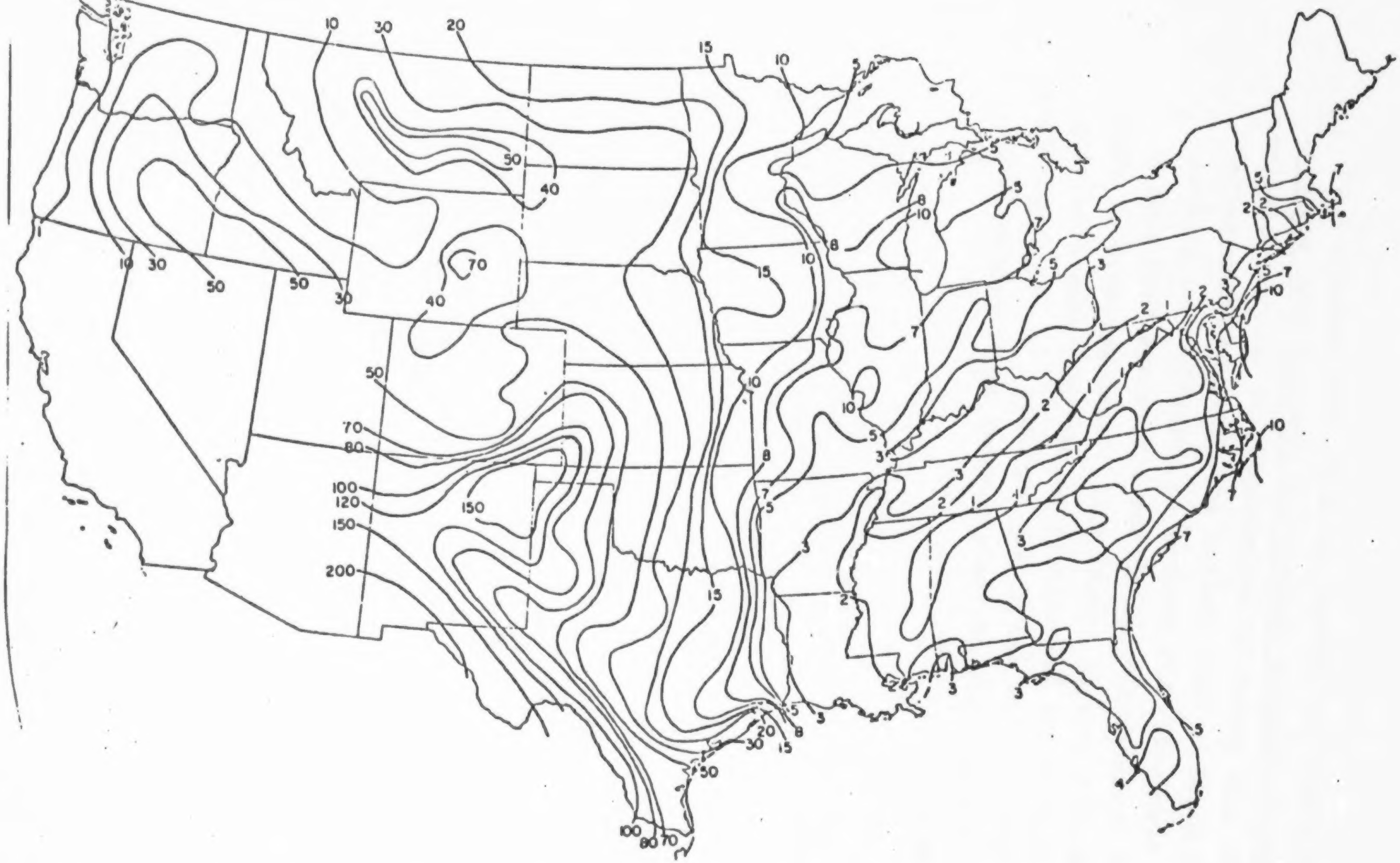
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Figure 3.11. Climatic factors for use in the wind erosion equation.

Source: Armbrust, D. V. and N. P. Woodruff, 1968.

of the modified wind erosion equation, see Appendix A of *Development of Emission Factors for Fugitive Dust Sources*.[12]

While this method of estimating wind erosion emissions is acknowledged to have limited accuracy, no other method has been proposed. All efforts to quantify wind erosion emissions which were found in the literature used some published USDA data on annual soil losses per acre as their basis. Because the emission rates per unit time from wind erosion are very low and highly variable, it is not possible to check the accuracy of the estimates by comparison with source sampling results.

4. SUMMARY

Eleven different mining operations were evaluated for their potential as fugitive dust sources. Although these operations do not have the same emission rates at all mines or in all mining industries, the intent of this report was to identify operations that may be major dust sources at mines.

Emission estimates for the mining operations are summarized in Table 4.1. These estimates should be used only after reviewing the descriptions in Chapter 3 relevant to their development and applicability. From these emission estimates and typical production rates, it can be determined that the approximate ranking of operations in order of decreasing emission rates is:

1. Overburden removal
2. Haul roads
3. Reclamation
4. Storage
5. Shovels/Truck loading
6. Transfer and conveying
7. Truck dumping
8. Blasting
9. Crushing
10. Waste disposal
11. Cleaning

Overburden removal is much more of a dust problem at surface coal mines and phosphate rock mines than at copper

Table 4.1. SUMMARY OF EMISSION ESTIMATES FOR MINING OPERATIONS

Operation	No. of emission estimates	Range	Units	Emission factors by industry				More data needed
				Coal	Copper	Rock	P_2O_5 rock	
Overburden removal	5	0.0008-0.45 0.048-0.10	lb/ton of ore lb/ton of overburden	0.05	0.0008			x
Blasting	2	0.001-0.16	lb/ton of ore					x
Shovels/Truck loading	5	neg-0.10	lb/ton of ore	0.05	0.05	0.05	NA	
Haul roads	4	0.8-2.2	lb/VMT	depends on speeds & controls				x
Truck dumping	3	0.00034-0.04	lb/ton of ore	0.02	0.02	0.04	NA	
Crushing	4	neg-0.7	lb/ton of ore	neg		0.044		x
Transfer & conveying	5	neg-0.2	lb/ton of ore				0.15	x
Cleaning	0	usually negligible			neg		neg	
Storage	5	0.0235-0.42 3.5-13.2	lb/ton of ore lb/acre/day	0.054	0.33	0.33 10.4	0.20	
Waste disposal	1	neg-14.4	ton/acre/yr					
Reclamation	1	use wind erosion equation	ton/acre/yr	depends on climate & soil				x

NA = not applicable

mines and rock quarries because of the greater amounts of overburden material handled in the former mines. Fugitive dust from reclamation is also associated primarily with coal mining and phosphate rock mining, and results from regrading of the spoils and wind erosion across the regraded surfaces. Haul roads are a major dust source at almost all mines, even though they are normally kept watered. The remaining operations generate dust through the handling or processing of the material being mined. Because of this, emission rates for most of them are highly dependent on the characteristics of the material as mined, i.e., moisture content, amount of fines, hardness.

Some of the operations create dust only in a few instances, such as copper tailings as a waste disposal source or air blowing as a cleaning process for coal. Waste disposal and cleaning operations generally are not significant fugitive dust sources at mines.

In order to estimate the fugitive dust emissions that stay suspended, an attempt has been made to express the emission factors in terms of the fraction less than 30 microns diameter wherever possible. Since data were not available to do this in all cases, some of the reported emission estimates may overstate the impact of those operations on a regional scale.

Table 4.1 also notes those operations for which more sampling or emission data are needed before reliable emission factors can be developed. More than half the operations, including those indicated to be the three largest sources at mines, are on this list. Many of these operations have not been sampled previously because of extreme difficulties in defining a representative process for sampling or because of special technical problems such as those encountered with measuring blasting or wind erosion emissions.

The air quality impact of fugitive dust from a specific mining industry is a function of the number of mines and the population exposed to their emissions. There are a relatively large number of coal mines. The dusty Western surface mines are in remote locations, but the Midwest surface mines, although less dusty, are often in areas of moderate population density. There are relatively few copper mines and these are in isolated locations except for the mines near Tucson, Salt Lake City, and Butte. In all three of these cities, fugitive dust from mining is shown to cause increased urban particulate concentrations. Stone quarries account for the most mining sites and they are often located near urban areas to reduce transportation costs. Phosphate rock is produced from relatively few mines, mainly in a limited area of west central Florida. With the exception of the cities of Lakeland and Winter Haven, population exposure to these mining emissions is low.

The air quality impact of mining emissions is attenuated by two additional factors. At many of the larger mines, the dust-producing activities occur in a pit that is considerably below surrounding ground level. Emissions from a depressed level have a lesser impact on ambient concentrations than the same emissions would have at ground level or from an elevated source. At other large mines, the property extends for many miles from the points of emission origin so that concentrations may be negligible by the time the dust plume reaches a property line.

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EVALUATION OF FUGITIVE DUST EMISSIONS FROM MINING

TASK 2 REPORT

ASSESSMENT OF THE CURRENT STATUS OF THE ENVIRONMENTAL ASPECTS OF FUGITIVE DUST SOURCES ASSOCIATED WITH MINING

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1. INTRODUCTION

This evaluation of fugitive dust air pollution from mining operations was undertaken to identify and compile currently available information on emission sources, regulatory approaches, monitoring techniques, control techniques, health and welfare effects, and research programs related to mining activities. An analysis of the assembled information will then be used as the basis for recommending near-term research and development programs which might be implemented by IERL/Cincinnati to fill gaps in the data base and further document effective control techniques for fugitive dust from mining opertions. For the more promising recommended R & D efforts, proposed technical approaches will also be developed.

The project is composed of three tasks, each of which will have its own task report:

Task 1 - Identification of fugitive dust sources associated with mining activities.

Task 2 - Assessment of current status of the environmental aspects of fugitive dust.

Task 3 - Recommendation of promising research areas.

The project is similar in scope to a study recently completed by Monsanto Research Corporation.[1] However, the intent of the present contract is to provide recommendations for specific research programs while the Monsanto Research study was designed to compile preliminary data on fugitive dust emissions from open sources and to recommend other sources for testing. Therefore, only the first of the three tasks overlaps to any extent with this previous work; their work has been utilized in preparing the Task 1 report.

The scope of the project includes both surface and underground mining plus related operations normally performed at the mine sites, such as crushing and storage. It does not include dust that is generated and remains underground or in an enclosed area--only emissions that affect ambient air quality. Also, it does not include emissions which occur off-site during shipping or at distant processing plants. Almost all particulate emissions at mines would be categorized as fugitive dust since they are generally emitted at ground level as a result of equipment activity or material transfer rather than from stacks.

The Task 1 report summarizes current knowledge concerning fugitive dust sources at mines and ranks the identified sources in order of relative importance from the standpoints of air quality impact and need for further research. This Task 2 report assesses the mining activities identified in the Task 1 report for the current status of information and technology concerning the major environmental aspects associated with their fugitive dust emissions. Included in this evaluation and listed by chapter numbers are:

2. Existing regulatory policies of federal, state, and local agencies directly or indirectly affecting the control of fugitive dust from mining sources.
3. "State-of-the-art" control technologies for each mining fugitive dust source.
4. "State-of-the-art" of techniques and equipment for measuring and monitoring ambient levels of fugitive particulates.
5. Effects of fugitive dust from mining sources on health and welfare.
6. A compilation of on-going and planned R & D studies related to mining fugitive dust sources.

Data for this report were obtained from a literature search, including PEDCo's files on fugitive dust sources, and from observations and personal contacts made on field trips during this study.

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2.0 REGULATORY POLICIES

Regulatory policies for the specific control of fugitive dust from mining sources are practically nonexistent. State Implementation Plans (SIP's) for most states contain very general fugitive dust emissions regulations which are often difficult to enforce, while some states have no regulations for fugitive dust at all. The Mining Enforcement and Safety Administration (MESA) indirectly regulates fugitive dust emissions through enforcement of personal respirable dust exposure standards. Some state's mining safety and reclamation laws also indirectly provide fugitive dust control through their overall safety and erosion prevention measures.

2.1 STATE AIR POLLUTION REGULATIONS

Because fugitive emissions from mines and other sources cannot be easily measured to provide control officials with estimates of the relative magnitude of their emissions, the potential improvement in air quality that may result from control of these sources cannot be easily estimated. This deficiency has been the major reason for the lack of attention given to fugitive emission sources in the past.

Primarily due to the magnitude of stack emissions from poorly controlled sources, (i.e., emissions from stacks of power plants and other industrial sources), but also because of the lack of available emission estimates for fugitive emission sources, few such sources were included in source emission inventories. Hence, the emission control regulations that were ultimately adopted by the State and local air pollution control agencies primarily addressed control of non-fugitive emission sources. In other words, the mass emission limitations (i.e., those that limit emissions to "no more than X pounds per hour") adopted by States are not directly applicable to fugitive emission sources. This is because compliance with such regulations can only be determined by measuring the total emissions from the process, generally through a stack. As previously indicated, this is extremely difficult for process sources with fugitive emissions. In cases where fugitive emissions can be measured it is generally too expensive for source operators to rely upon the measurement technique to determine source compliance.[1]

Some states did, however, adopt general regulations to address the fugitive emissions problem. Four general techniques have been used to minimize fugitive emissions, two of which are of limited value. The first involves the general nuisance provision which most pollution control agencies

1

have included within their regulatory scheme. Under the nuisance provisions, emissions from a source are not allowed if they cause any person to suffer health or welfare effects. Nuisance regulations can be useful in some cases when the responsible sources can be specifically identified, and when such source is agreeable to minimize emissions. Generally, comprehensive source emission control programs do not result from action taken under nuisance regulations. The second regulatory approach which also has limited value requires source operations with fugitive emissions to take "reasonable precautions to prevent fugitive emissions from becoming airborne." These regulations are generally difficult to enforce since reasonable precautions are not specifically defined.

The difficulties associated with use of the two regulatory approaches described above have led to the development of the third and more successful regulatory approach for the control of fugitive emissions, the requirement for the source operator to install, operate and maintain specified equipment to capture and control fugitive emissions from becoming airborne. "Equipment standards," as they are termed, are enforceable and are believed to be effective for the semi-confined control of many fugitive dust sources; however, these types of regulations are not in general applicable to the widespread nature of mining sources. The fourth regulatory technique used by control agencies is the visible emissions regulation. Such regulations generally do not permit the presence of visible emissions beyond the source's property line. With the exception of rock quarries located within population centers, this type of regulation is not amenable to most other mining sources, considering the expansive areas and remoteness typical of most mines.

The Missouri Air Conservation Commission's fugitive dust regulation prohibits fugitive dust or particles larger than 40 microns beyond the source's property line. The Commission employs microscopy to "fingerprint" the fugitive dust particles from samples taken adjacent to the source's property line in establishing the origin of the particles, i.e., the sample particles are compared under the microscope with dust taken from potential source/s to identify their origin. Enforcement of the regulation via this approach has been implemented at rock quarries, grain mills, and other fugitive dust sources.

Table 2.1 presents a nationwide summary of particulate ambient air quality standards and fugitive dust regulations by state. As can be seen, none of the regulations specifically regulate fugitive dust from mining sources.

2.2 MESA REGULATIONS

Dust regulations enforced by the Department of the

Table 2-1. SUMMARY OF STATE AMBIENT AIR QUALITY STANDARDS AND FUGITIVE DUST REGULATIONS

Jurisdiction	Primary Standard	Secondary Standard	Fugitive Dust and Dustfall
Alabama	Federal (75 $\mu g/m^3$ annual geometric mean of 24 hr. concentration)	Federal (60 $\mu g/m^3$ annual geometric mean of 24 hr. concentration)	No fugitive dust beyond property line. Abatement: Reasonable precautions, plus first 3 paragraphs of Federal model.
Alaska	Federal	Federal	No visible dust past property line. Abatement: First 3 paragraphs of Federal model.
Arizona	Federal secondary	Air Quality Goal: 100 $\mu g/m^3$ maximum 24-hr. average	Fugitive dust from hauling, handling crushing or conveying of materials must be controlled by reasonable means.
Arkansas	Federal	Federal	May not exceed 75 $\mu g/m^3$ for any 24-hr. period or 150 $\mu g/m^3$ for any 30-minute period (measured on property and subtracting background). Abatement: Reasonable precautions. Dust fall: maximum 15 tons/mile^2/month. Particles larger than 60 microns may not exceed 120/cm^2/24 hrs.
California	Nonvehicular standards and regulations are set by counties		Fugitive dust regulations are devised by each county. Those with applicable regulations call for "reasonable precautions."
Colorado	Federal	Federal	If emissions are judged by a panel to be "objectionable," may require use of "best practical method" of control. Controls must be applied during non-working hours as required to control dust. No visible emissions may cross property line.
Connecticut	Federal	Federal	Reasonable precautions, plus Federal model, except paving of roads not required and agricultural operations need not suppress dust. No discharge beyond property line if: 1) visible near ground, 2) impinges on building or structure.

Table 2-1 (continued). SUMMARY OF STATE AMBIENT AIR QUALITY STANDARDS AND FUGITIVE DUST REGULATIONS

Jurisdiction	Primary Standard	Secondary Standard	Fugitive Dust and Dustfall
Delaware	70 $\mu g/m^3$ annual geometric mean of 24-hr. concentration. 200 $\mu g/m^3$ 24-hr. average concentration, not to be exceeded more than once per year. 500 $\mu g/m^3$ one hour average.	**Federal**	Water, chemicals or approved techniques must be used to control dust emissions during demolition, grading, land clearing, excavation and uses of unpaved roadways.
District of Columbia	**Federal**	**Federal**	Federal model, except that agricultural operations receive no specific mention.
Florida	Federal secondary, except in Dade, Broward and Palm Beach Counties, where the following apply: 50 $\mu g/m^3$ annual geometric mean. 180 $\mu g/m^3$ maximum 24-hr. concentration.		Fugitive dust in excess of process emissions rate is prohibited. Reasonable precautions to abate fugitive dust are required.
Georgia	**Federal**	**Federal**	Federal model
Hawaii	100 $\mu g/m^3$ during any 24-hrs. 55 $\mu g/m^3$ annual arithmetic mean during any 12-month period.		No visible dust past property line. Ground level concentration at a point selected by the Department may not exceed 150 $\mu g/m^3$ above background. Dust fall may not exceed 3.0 grams per square meter per 14 days. Abatement by Federal model, except that Director may determine that "best practical" measures are sufficient.
Idaho	**Federal**	**Federal**	"All reasonable precautions" plus Federal model.
Illinois	Federal, plus no degradation of regional air quality permitted.	**Federal**	No emissions larger than 40 microns mean diameter. No emissions beyond property line visible when looking toward zenith. Not applicable in winds greater than 25 mph.
Indiana	**Federal**	**Federal**	No visible dust over property line. May not exceed 166 percent of upwind values, nor more than 50 $\mu g/m^3$ at ground level above background more than 60 minutes.

Table 2-1 (continued). SUMMARY OF STATE AMBIENT AIR QUALITY STANDARDS AND FUGITIVE DUST REGULATIONS

Jurisdiction	Primary Standard	Secondary Standard	Fugitive Dust and Dustfall
Iowa	**Federal**	**Federal**	No fugitive dust beyond property line. Federal model for abatement, except that no mention is made of agricultural dust suppression or paving of roads.
Kansas	**Federal**	**Federal**	Airborne particulates at ground level at property line may not equal 2.0 μg per cubic meter, above background, more than 10 min/hr.
Kentucky	**Federal**	**Federal**	No fugitive dust beyond property y line, plus Federal model, except (1) no requirement that roads be paved, and (2) agricultural operations can create airborne dust if no nuisance created. Secondary dust fall standard: 15 ton/mi^2/month.
Louisiana	**Federal**	**Federal**	Dust fall: 20 tons/square mile/month Coefficient of haze: 0.6 coh/1000 lineal ft., annual geometric mean; 0.75 coh/1000 lineal ft., annual arithmetric mean; 1.50 coh/1000 lineal ft., 24-hr. average. Abatement by Federal model
Maine	100 μg/m^3 24-hr average, 50 μg/m^3 annual geometric mean of 24-hr averages.		
Maryland	"Primary: lowest concentrations attainable by reasonably available control methods, but not to exceed concentrations set forth as "secondary standards."	Annual arithmetric average: "More adverse": Lower Limit Upper Limit Serious 65 μg/m^3 75 μg/m^3 75 μg/m^3 daily average, once per year: 140 μg/m^3 160 μg/m^3 160 μg/m^3 dustfall, mg/cm^2/mo 0.35 0.50 0.50	Federal abatement model, except no mention of agricultural operations.

Table 2-1 (continued). SUMMARY OF STATE AMBIENT AIR QUALITY STANDARDS AND FUGITIVE DUST REGULATIONS

Jurisdiction	Primary Standard	Secondary Standard	Fugitive Dust and Dustfall
Massachusetts	Federal	Federal	Reasonable precautions required. Fugitive dust from process industries, from transport or handling of materials, or from construction use and maintenance of roads may not "contribute to a condition of air pollution."
Michigan	Federal	Federal	Treated as a nuisance. Area of cut and fill open at one time is limited.
Minnesota	Federal	Federal	"Avoidable amounts" of dust must not become airborne. Director may order reasonable measures to be taken, including paving and frequent cleaning of roads, application of dust free surfaces, use of water and maintenance of vegetative ground cover.
Mississippi	Federal	Federal	Fugitive particulate matter must not become airborne as a result of handling, storage, or transport of any material. Dust fall may not exceed background levels by 5.25 grams/m^2/month on adjacent property.
Missouri			Reasonable precautions required. No fugitive dust or particles larger than 40 microns permitted beyond property line. Concentrations at property line: Suspended particulates 80 $\mu g/m^3$ 6-month geometric mean 200 $\mu g/m^3$ 2-hr arithmetic mean, for no fewer than 5 samples per year.
Montana	Federal	Federal	Reasonable precautions must be taken; no "controllable" particulate matter may be emitted. Specific measures may be ordered by the Director.

Table 2-1 (continued). SUMMARY OF STATE AMBIENT AIR QUALITY STANDARDS AND FUGITIVE DUST REGULATIONS

Jurisdiction	Primary Standard	Secondary Standard	Fugitive Dust and Dustfall
Nebraska	Federal	Federal	No visible dust may pass over property line. Measures to control fugitive dust may include paving, frequent cleaning of roads, application of dust free surface, planting and maintenance of vegetation cover.
Nevada	Federal	Federal	Reasonable precautions are required. No visible airborne dust may cross property line.
New Hampshire	Federal Secondary		Roads, storage areas, etc. shall be controlled to confine dust.
New Jersey	Ambient air quality must be highest achievable at present state of the art, but in no case may it be worse than the Federal primary standard.	Federal	No standard or model.
New Mexico	*150 $\mu g/m^3$ 24-hr average 110 $\mu g/m^3$ 7-day average 90 $\mu g/m^3$ 30-day average *60 $\mu g/m^3$ annual geometric mean		No standard or model.
New York	State includes 4 "levels" from Level I: sparse population, to Level IV: Metropolitan. Short term (all levels) average 24-hr. concentration shall not exceed 250 $\mu g/m^3$. Long term: during 12 months, 50 percent of 24 hr. concentrations may not exceed: Level I: 55 $\mu g/m^3$ Level III: 65 $\mu g/m^3$ Level II: 65 $\mu g/m^3$ Level IV: 75 $\mu g/m^3$ and 84 percent of 24-hr values shall not exceed: Level I: 45 $\mu g/m^3$ Level III: 100 $\mu g/m^3$ Level II: 85 $\mu g/m^3$ Level IV: 110 $\mu g/m^3$		Dust fall: During any 12 months, 50 percent of 30-day values shall not exceed: (mg/cm^2/mo) Level I: 0.30 Level III: 0.40 Level II: 0.30 Level IV: 0.60 During any 12 months, 84 percent of 30-day values shall not exceed (mg/cm^2/mo): Level I: 0.45 Level III: 0.60 Level II: 0.45 Level IV: 0.90

* Together comprise Federal secondary.

Table 2-1 (continued). SUMMARY OF STATE AMBIENT AIR QUALITY STANDARDS AND FUGITIVE DUST REGULATIONS

Jurisdiction	Primary Standard	Secondary Standard	Fugitive Dust and Dustfall
North Carolina	Federal Secondary		Asphalt plants must limit fugitive dust to stack outlet. Roads must be treated around plant. In road construction, use of dust control on haul roads and water sprays over crushers for stone and aggregate handling are required.
North Dakota	Federal Secondary		Dust fall: 15 tons/mi^2/mo, maximum 3-month arithmetic mean in residential areas. 30 tons/mi^2/mo, applies to heavy industry areas. 0.4 coefficient of haze/1000 lineal feet, maximum annual geometric mean. "Reasonable precautions" plus Federal model.
Ohio	Federal Secondary		Reasonable precautions plus Federal model.
Oklahoma	Federal	Federal	Reasonable precautions to control fugitive dust are mandatory.
Oregon	Highest and best technology must be applied. Standards measured at "primary stations:" 60 $\mu g/m^3$ annual geometric mean; 100 $\mu g/m^3$ 24-hr concentration not to be exceeded by 15 percent of monthly samples; 150 $\mu g/m^3$ 24-hr concentration.		Abatement by Federal model, less mention of agricultural operations of paving roads. Stockpiles of materials should be enclosed where other means do not control dust.
Pennsylvania	Federal	Federal	Dust fall: annual average 0.8 mg/cm^2/mo. 30-day average 1.5 mg/cm^2/mo. In all roadwork and land clearing fugitive dust must be confined to property, and not exceed 150 particles per cubic centimeter at property line. Abatement by Federal model, except no call for hoods, fans, or covering of trucks.

Table 2-1 (continued). SUMMARY OF STATE AMBIENT AIR QUALITY STANDARDS AND FUGITIVE DUST REGULATIONS

Jurisdiction	Primary Standard	Secondary Standard	Fugitive Dust and Dustfall
Puerto Rico	Federal	Federal	No fugitive dust in visible quantities may be permitted to cross property line. Abatement by Federal model.
Rhode Island	Federal	Federal	No emissions to air from handling, transportation or storage of materials. Abatement by reasonable precautions during construction.
South Carolina	60 μg/m^3 annual geometric mean 250 μg/m^3 24-hr average		Dust control measures must be used on premises and roads of mining, quarrying and other unenclosed operations.
South Dakota	Federal Secondary		
Tennessee	Federal	Federal	Visible dust emissions may not pass proper property line more than 5 min/hr or 20 min/day. Abatement by Federal model, first three paragraphs only.
Texas	Federal Emissions from any source may not exceed: 100 μg/m^3 average over 5 hrs. 200 μg/m^3 average over 3 hrs. 400 μg/m^3 average over 1 hr.	Federal	Materials-handling dust must be controlled by use of water or chemicals, use of hoods and fans, and covering or wetting truck-bed loads. During road construction, dust suppression is required on all haul roads.
Utah	Federal	Federal	
Vermont	45 μg/m^3 annual geometric average 125 μg/m^3 daily average		Reasonable precautions must be exercised in road construction activities.

Table 2-1 (continued). SUMMARY OF STATE AMBIENT AIR QUALITY STANDARDS AND FUGITIVE DUST REGULATIONS

Jurisdiction	Primary Standard	Secondary Standard	Fugitive Dust and Dustfall
Virginia	Federal, except in National Capital Air Quality Control Region, where Federal secondary standards must be met.	Federal	Federal model, except control of agricultural emissions are not required.
Virgin Islands	Federal	Federal	All reasonable measures, including watering and coating of roads, must be used during road construction.
Washington	Federal Secondary		Reasonable precautions are required.
West Virginia	Federal	Federal	
Wisconsin	Federal	Federal	Abatement by Federal model.
Wyoming	Federal Secondary coh-0.4/1000 lineal ft. annual geometric mean		Dust fall: 5 $gm/m^2/mo$ for any 30-day period in a residential area. 10 $gm/m^2/mo$ for any 30-day period in an industrial area. Abatement by Federal model.

SOURCE : HNTB

Interior's Mining Enforcement and Safety Administration are designed to protect the mine worker from exposure to hazardous dust concentrations. The regulations are primarily applicable to underground mines, where the confined atmosphere tends to concentrate the dust generated; however, dust emissions from the surface mining activities can also be excessive at times, and are therefore also covered by the MESA regulations. The most significant aspect of these laws, which indirectly regulate fugitive dust emissions as well, involves maintenance of the average concentration of respirable dust in the mine atmosphere below the threshold limit values adopted by the American Conference of Governmental Industrial Hygienists (ACGIH) in their 1973 edition of "TLV's Threshold Limit Values for Chemical Substances in Workroom Air Adopted by ACGIH for 1973". For example, MESA enforces a coal mine respirable dust limit of 2.0 mg/m^3*, the TLV specified by ACGIH.

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* 36CFR 12213, Mineral Resources - Dust Standards, Sec. 70.100 (b) June 29, 1971.

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3.0 CONTROL METHODS

The applicability of the various methods for controlling fugitive dust emissions from individual mining operations has been discussed in the Task 1 Report - "Identification of Fugitive Dust Sources Associated with Mining". This section discusses each of these control methods, and summarizes their efficiencies and costs.

Unlike control methods for particulate emissions from conventional stationary and mobile sources, those for fugitive dust have not been researched and developed appreciably; consequently, they are not extensively documented in the literature. With few exceptions, all of the fugitive dust controls identified in the literature and observed first hand during mining operation visits in this and previous studies, were applications of one or a combination of three basic techniques: watering, chemical stabilization, and reduction of surface wind speed across exposed sources.

3.1 WATERING

Watering generally requires a low first cost, but provides the most temporary dust control. Depending on the nature of the dust-producing activity water may be an effective dust suppressant for only a few hours or for several days. In addition to the direct cohesive force of a film of moisture in holding surface particles together, watering is also effective in forming a thin surface crust that is more compact and mechanically stable than the material below and which is less subject to dusting even after drying. However, this crust and its dust-reducing capability are easily destroyed by movement over the surface or by abrasion from loose particles blown across the surface. Therefore, watering must be repeated frequently to re-form the moisture film or surface crust.

An in-depth discussion of the effect of surface soil moisture on soil erodibility can be found in USDA Technical Bulletin No. 1185, Soil Conditions That Influence Wind Erosion.[1]

It should be pointed out that fugitive dust problems from mining are most prevalent in areas of the country with arid climates and lack of natural surface moisture. As a corollary to this, water is a scarce resource in these areas, and not readily available as a material for air pollution control.

Applicability

Watering in the mining industry is primarily employed to control dust emissions from haul roads. Watering can be used to control dust emissions from overburden removal, crushing, storage, and waste disposal, but its use for these operations is not widespread.

Haul roads at mines are routinely watered for dust suppression during all periods when water on the road surface does not create a safety hazard (generally when temperatures are above freezing). The water is usually applied by large tank trucks equipped with a pump and directional nozzles which spray the road surface and adjacent shoulders and berms. Fixed pipeline spray systems have also been used on main haul roads that are relatively permanent. At some western mines, runoff from haul roads is diverted to settling ponds placed at intervals along the roadway.

If the use of water can be tolerated, it can be sprayed at crusher and shaker screen locations to keep the material moist at all stages of processing. The addition of water may, however, cause blinding of the finest size screens, thereby reducing their capacity.

Watering alone is seldomly used to suppress dust from overburden removal, storage, and waste disposal operations because of the vast area and quantities of material which must be covered and because of the logistics and related costs of supplying the required amounts of water to the remote areas in which these operations are usually located. Control of overburden removal dust emissions by watering is

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also hampered by the continuous exposure of dry material surfaces associated with this operation. Much research has been done on the stabilization of waste tailings to prevent air and water pollution by mining companies and the Bureau of Mines' Salt Lake City Metallurgy Research Center. Radically different methods -- chemical, physical, and vegetative -- have been tested, often successfully, on inactive tailings piles. Active tailings generally have a moist surface from new deposits and therefore are not susceptible to wind erosion.

The effect of watering on dust emissions from storage piles and surrounding areas at mine sites is quite temporary, due to continuous turnover of material which exposes new surfaces to wind erosion. Watering sometimes reduces ability to handle the material easily. In addition, it is difficult to enforce watering regulations for this type of source.

A planned Bureau of Mines research project,[2] discussed in detail in Section 6, will evaluate the effect of water infusion of coal beds on respirable dust during mining operations.

3.2 CHEMICAL STABILIZATION

Several types of chemicals have been found effective in reducing dusting when applied on mining fugitive dust sources. These chemicals utilize different properties for dust suppression and are generally categorized by their composition -- bituminous, polymer, resin, enzymatic, emulsion, surface-active agent, ligninsulfonate, latex, etc. It is estimated that over 100 chemical products are presently marketed or are under development specifically as dust control agents.[3] Many of these are by-products or wastes from the production of other materials. A partial list of commercially available chemical stabilizers is presented in Table 1.

With the wide range of characteristics available in commercial products, a chemical stabilizer can be selected with maximum efficiency for each dust control application. Some of the materials "heal" if the treated surface is disturbed, but many do not re-form. The life of the treated surface under natural weathering also varies widely with different chemicals. Selection of the appropriate material may require that several other criteria be checked for compatibility, including effect on vegetative germination and growth, application method, possible contamination of material being protected from dusting, and correct chemical for texture of specific soil or material. Although no single comprehensive summary of dust suppressant chemicals and their properties was found, several evaluations have been prepared for different chemicals on a single type of fugitive dust source.

Applicability

Chemical stabilizers have been used to a limited extent to control dust from mining haul roads, storage piles, and inactive tailings piles.

Various chemicals may be added to the water or applied separately to the haul road surface to improve binding and reduce dusting. Application of a surface chemical treatment for dust suppression from haul roads is a relatively inexpensive control method. However, in tests on public roads conducted by several different highway departments, no commercial material has been found which retains its effectiveness over a reasonable period of time, i.e., two months, under traffic conditions. Most of the treated surfaces abrade badly to the depth of penetration of the chemical, which would be more of a factor with heavy bearing loads experienced by mining haul roads; others which maintain a stabilized surface with traffic are water-soluble and lose their effectiveness after rains. Several surface treatment chemicals are presently under development or are being tested. Available technology for this method may increase greatly within the next few years.

A few successful special applications of surface treatment have been found. On non-traffic surfaces such as roadway shoulders, chemical soil stabilization has proven highly effective in reducing the dust produced by air turbulence from passing vehicles; however, this type of control would not be very effective for haul road berm stabilization, since these berms are continuously disturbed by the passing trucks.

Another chemical dust suppressant method involves working the stabilization chemical into the roadbed to a depth of two to six inches. This construction technique has been used extensively on rural unpaved roads in parts of the country where locally available petroleum by-products provide a cheap material for oiled earth roads. Many highway departments are testing this type of road to reduce dust problems, but it has found limited application thus far for mining haul roads. Actual paving of haul roads with a bituminous material has also found limited application and is restricted economically to haul roads which are permanent. Savings in haul truck tire wear are reportedly achieved with paved haul roads, in addition to dust control.

Chemical stabilizers react with dry inactive tailings piles in the same manner they react with soils to form a wind-resistant crust or surface layer. Of 65 chemicals for which test results have been recorded, the resinous, polymer, ligninsulfonate, bituminous base, wax, tar and pitch products have proven most successful in stabilizing mineral wastes.[4] Most of the chemicals have demonstrated a long-term effectiveness in this application. Application can be accomplished by truck, piping spray systems, or plane--1000 acres of the inactive Kennecott copper tailings area west of Salt Lake City have been successfully stabilized by aerial application of chemicals.

Recently, several tailings piles have been successfully planted by use of a combination chemical-vegetative technique. The chemical stabilizers alleviate the problems of sandblasting and highly reflective surfaces and hold more water near the surface of the otherwise porous tailings, thus creating a more favorable environment for vegetation growth. Chemicals are selected which do not have an inhibitory effect on the plants.

An effective, long lasting method of dust control from storage piles is the addition of chemicals to the water sprays. Rather than acting as chemical soil stabilizers to increase cohesion between particles, most of these chemicals work as wetting agents to provide better wetting of fines and longer retention of the moisture film. Some of these materials remain effective without rewatering on piles stored for weeks or months. The system of application can be a continuous spray onto the material during processing or a water truck with hose and spray nozzle. The limiting factor here is the possibility of contaminating the stored material with the chemical dust suppressant.

3.3 REDUCTION OF WIND SPEED

Wind can contribute significantly to all of the mining fugitive dust sources, both by erosion of the exposed surfaces of storage areas, tailings piles, and reclaimed areas and by direct transport of the dust generated by the other mining operations. Therefore, reduction of surface wind speed across the source is a logical means of reducing emissions. This takes such diverse forms as windbreaks, enclosures or coverings for the sources, and planting of tall grasses or grains on or adjacent to exposed surfaces. The vegetative techniques all need a soil which supports growth -- containing nutrients, moisture, proper texture, and no phytotoxicants. These requirements, especially adequate moisture, are often not available in mining areas and are often the reason that natural protection against wind erosion is insufficient.

Applicability

The large size of most of the mining fugitive dust sources precludes the widespread use of enclosures or wind barriers from practical considerations. Exceptions are: mats used for safety purposes during blasting at construction areas could be employed on a limited, site-specific basis for small blasts at mine sites adjacent to populated areas to help retard dust transport; silos and other enclosed storage facilities are sometimes employed for storage of relatively small quanitities of mined material; enclosed conveying systems with hooding connected to control devices such as scrubbers or baghouses have been used; and hooding can also be employed to control the fugitive dust from truck dumping, crushing, and cleaning operations. A natural wind barrier is usually created for overburden removal and shovel/truck loading by the depressed location of these operations.

Reclamation of mined areas is both a source of and a control technique for fugitive dust, i.e. the short-term reclamation operations such as regrading and revegetation which produce fugitive dust are designed to ultimately result in an area which is stabilized and protected over the long-term from the erosion mechanisms of wind and runoff. Reclamation processes have been discussed in detail in the Task 1 Report.

Many materials have been tried for physical stabilization of fine tailings. The material most often used is rock and soil obtained from areas adjacent to the wastes to be covered. Soil provides an effective cover and a habitat for encroachment of local vegetation. However, it is not always available in areas contiguous to the tailings piles and, even where available, it may be too costly to apply. Crushed or granulated smelter slag, another waste product, has been used to stabilize tailings. Another physical method of control which has been employed is covering with bark or harrowing straw into the top few inches of tailings.

Successful vegetative stabilization produces a self-perpetuating ground cover or fosters entrapment and germination of native plant seeds that will grow without the need for irrigation or special care. Several mining companies have planted old tailings accumulations in efforts to achieve both wind erosion control and an attractive site. Resistance to vegetative growth was encountered in these efforts due to excessive salts and heavy metals in the tailings, windblown sands destroying the young plants, high temperatures, and lack of water on the tailings piles.

The effectiveness of vegetative cover in reducing windblown dust is dependent primarily on the density and type of vegetation that can be grown on the resistant tailings. In a recent study, Bureau of Mines researchers were able to grow wheat and other small grain at a density of 2.4 plants per square foot on tailings.[5] This is equivalent to 1000 to 1500 lb per acre of stubble. Substituted into the wind erosion equation with a soil type of sand, unridged surface, and an unsheltered length of 2000 feet, the above vegetative densities reduce calculated emissions by 50 to 80 percent. An average control of 65 percent is proposed, with possible modifications of this value based on the density of growth on the tailings.

3.4 CONTROL EFFICIENCIES AND COSTS

Estimated percent reductions achieved by the fugitive dust control techniques found to be effective for mining operations and their related costs are presented in Table 3-2.

Control efficiency references listed as "PEDCo Estimates" are based on observations during mine visits and/or conversation with personnel associated with mining, both private and governmental.

It should be emphasized that each of the control methods has a wide range of efficiencies and costs rather than the single average value discussed here. Recent cost data represent total costs, including application. The source of the cost data is also identified. Numbers shown in the cost "Reference" column refer to publications from the reference list.

Table 3-2. SUMMARY OF CONTROL EFFICIENCIES AND COSTS FOR MINING FUGITIVE DUST SOURCES

Source	Control			Control cost		
	Applicable Control Method/Comments	Estimated Efficiency	Reference	Unit Cost $	Units	Reference
Overburden Removal	Watering/Rarely practiced	50%	PEDCo Estimate	no data		
Blasting	Mats/Very rarely employed	no data		no data		
Shovels/Truck loading	Watering/Rarely practiced	50%	PEDCo Estimate	no data		
Haul Roads	Watering/By far the most widely practiced of all mining fugitive dust control methods	50%	(6)	no data		
	Surface treatment with penetration chemicals/Employment of this method increasing	50%	(6)	1000-3000	mile	Chemical Suppliers
	Paving/Limited practice	90-95%	PEDCo Estimate	no data		
Truck Dumping	Watering/Rarely Practiced	50%	PEDCo Estimate	no data		
	Ventilated enclosure to control device/Rarely employed	85%-90%	PEDCo Estimate	no data		
Crushing	Adding water to material to be crushed/Fairly commonly practiced	95%	PEDCo Estimate	negligible		
Transfer and Conveying	Enclosed conveyors/Commonly employed	90%-99%	PEDCo Estimate	no data		
	Hooding with control devices at transfer points/Rarely employed	85%-99% (depends on control devices)	Based on efficiency of applied control devices	no data		
Cleaning	Very little control needed since basically a wet process					
Storage	Continuous spray of chemical on material going to storage piles/ arely practiced	90%	(7)	20-50	100 tons/lb	(8), (9)
	Watering (sprinklers or trucks)/ Rarely practiced	50%	PEDCo Estimate	no data		
Waste Disposal Tailings Piles	Chemical stabilization/ Limited practice	80%	a	150-400 250-600	acre acre	(10) (11)
	Vegetation/Commonly practiced	65%	Calculated from Wind Erosion Equation	200-450 (hydroseeding)	acre	(11)
	Combined chemical-vegetative stabilization/Rarely employed	90%	PEDCo Estimate	100-150	acre	(4)
	Slag cover/Limited practice	95%-99%	PEDCo Estimate	350-450	acre	(11)

[a] Similar to efficiency determined in a study of chemical stabilization of construction areas, cuts and fills(1).

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4.0 MEASURING AND MONITORING TECHNIQUES

This section summarizes the state-of-the-art in ambient air monitoring of fugitive dust emissions sources. Preliminary monitoring to determine emission factors for surface mining operations has been accomplished.[1] This work, however, was not extensive and it did not include specific monitoring of many of the sources characterized as being the most significant fugitive dust sources in the mining industry. A PEDCo study[2] indicates that the four mining industries that are probably the largest sources of fugitive dust are coal, copper, crushed stone, and phosphate rock mining. The same study summarized the major sources of fugitive dust emissions within each mining industry and identified the source potential for fugitive dust emissions. Table 4.1 summarizes that information for surface mining.

Although surface mining operations have not been monitored extensively the techniques used to monitor other fugitive dust sources and consequently to derive emission factors for those sources[2,3,4] apply to monitoring mine operations. The nature of the particulates and operations of most of the fugitive dust sources previously studied is similar to that of the sources in the mining industries.

Table 4.1 DUST-PRODUCING OPERATIONS BY MINING INDUSTRY

	Mining industry			
Operation	Coal	Copper	Rock	P_2O_5 rock
Overburden removal	x	+	+	x
Blasting	+	x	x	o
Shovels/Truck loading	x	x	x	o
Haul roads	x	x	x	o
Truck dumping	+	x	x	o
Crushing	+	+	x	o
Transfer and conveying	+	+	+	x
Cleaning	o	o	o	o
Storage	+	+	x	x
Waste disposal	+	x	o	+
Reclamation	x	o	+	x

x = usually a major source

+ = a minor or occasional source

o = usually not a dust source

Each fugitive dust source has special characteristics that influence:

- monitor siting,
- sampling schedules and technique,
- choice of monitoring equipment.

Some of the important source characteristics that may a~~e~~ffect sampling schemes are:

- physical characteristics of the particles emitted,
- controls applied to the source,
- source activity levels,
- local meteorological conditions,
- proximity of sources within the industrial site boundaries,
- plume development and particle transport properties.

A previous study[5] documented the relationships between these characteristics, the source type, and the sampling plan. A comprehensive summary of techniques or guidelines for monitoring fugitive dust emissions is not available.

4.1 MONITOR SITING

Several monitors are required to adequately monitor fugitive dust emissions from surface mining sources. Work performed to date has been oriented toward development of emission factors and the collection of technical data necessary to characterize the plume development and particle transport properties of emissions from various fugitive dust sources. The quantitative estimation of the number and size of particles that are considered to be suspended particulates, i.e. those that do not settle within a short distance from the site, has been a primary goal of many of the emission factor studies. This is especially important, since the suspended particle fraction includes the smaller particles (Avg. = 3.5 µm diameter) and these particles, being the respirable fraction, have the most direct impact on public health. Work has not been published regarding the optimal placement of monitors throughout an area that includes surface mining operations. The techniques described here are summarized from previous studies and they apply to monitoring individual sources.

Monitors are usually located along a line from the source in the mean wind direction. An upwind monitor is usually used to determine background concentrations from from sources upwind of the primary source (the source being monitored).[1,5] One monitor is placed downwind and as near the primary source as possible without interfer~~r~~ing with source activity, i.e. movement of equipment, etc. This monitor should receive the full impact, including the larger, settleable particulates, of the source emissions. A second monitor should be placed downwind from and in line with the first monitor. This monitor should receive primarily the impact from the smaller particles, i.e. those that do not readily settle, and it will provide the best esimate of the emissions that will impact the ambient air quality from this source. The distance of this monitor, which is referred to as a boundary site, from the primary source can be estimated by considering the source type. Several particle deposition rate studies[6] and correlations

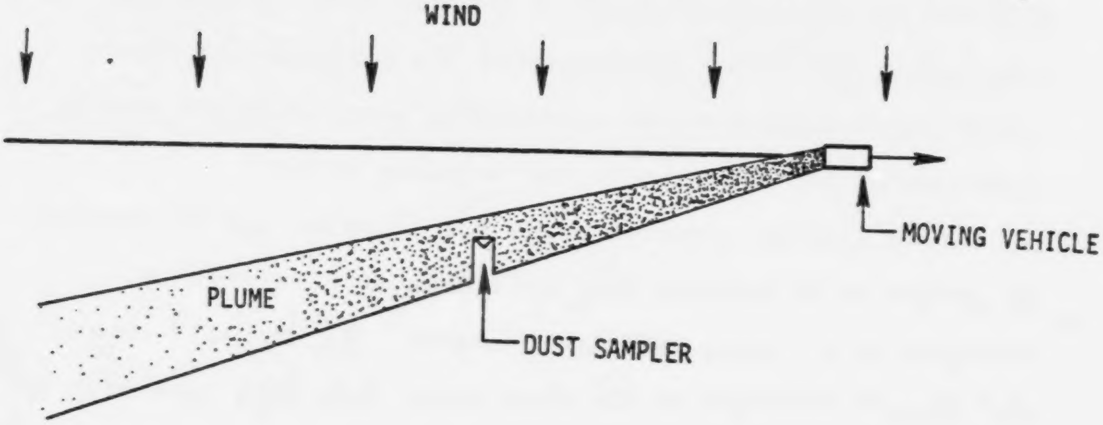
WIND
MOVING VEHICLE
PLUME
DUST SAMPLER

Figure 4-1. Overhead view of dust plume from moving point source.

from emission factor work[3] are the best available sources for determining the optimal placement of the boundary site. Two or more additional boundary sites may be necessary to compensate for fluctuations in the wind direction component downwind from the source. These monitors are usually on a circle whose radius is the distance from the primary source and the first boundary site. A mathematical formula was applied in one study[1] to determine the placement of these additional boundary sites. Increased sampler height may be substituted for distance at the boundary sites.[5]

Some sources, unpaved roads for example, may be treated as moving point sources that emit dust at a relatively constant rate during vehicle movements. Figure 4.1[3] shows the general movement of the dust plume from this type of source. The sampler must be placed at a sufficient distance from the source to allow for adequate plume development. The plume characteristics depend on the vehicle speed.

Monitoring of individual static and mobile fugitive dust sources represents the work completed to date. Guidelines are not available to assist with determining the number of sites necessary, the height of the sampler above ground, and the source-sampler distance. A review of much of the previous work on fugitive dust emissions, however, can provide some informal guidelines. A recent publication[6] provides guidance for monitoring industrial process fugitive particulates by three basic methods:

(1) Quasi-stack sampling.

(2) Roof monitor sampling.

(3) Upwind-downwind sampling. however, only the upwind-downwind technique has any application to mining processes.

4.2 MONITORING EQUIPMENT

Fugitive dust studies have used five types of sampling equipment, most of which are adaptations of the high volume (hi vol) sampler:

- hi vol
- wind direction hi vol
- vertical profiler
- hi vol with Andersen modification
- beta gage

4.2.1 Hi Vol Samplers

The hi vol sampler is an apparatus for collecting a relatively large volume of air (1.5 to 2.0 cubic meters per minute) and capturing its suspended particulate matter on a filter. The sampler consists of a motor-driven blower and a supporting screen for the filter ahead of the blower. During the sampling operation the sampler is supported in a protective housing so that the 8" x 10" surface of the filter is in a horizontal position. The sampler incorporates a continuous flow device for recording the actual air flow over the entire sampling period. A 7-day clock switch starts and stops the sampler.

The major limitation of this sampler is that it samples large diameter particles with low efficiency.[7] Consequently, modifications of this sampler may be required for selected source monitoring, e.g. soil or unpaved roads where the majority of the particles are large particles.

4.2.2 Wind Direction Hi Vol

This is a standard hi vol activated by signals from a wind instrument. The sampling occurs only when the wind is in the predetermined direction. A recent development[8] has potential for providing more comprehensive wind directional data than the conventional directional hi vol. This instrument uses a standard hi vol sampler and collects samples on filter slides by drawing air through a porting arrangement activated by an associated wind vane. This instrument is currently being tested. It was developed specifically to collect data that would help identify major contributing pollutant sources.

4.2.3 Vertical Profiler

One study[3] used a vertical profiling tower developed by Midwest Research Institute (MRI) to sample emissions from unpaved roads. The profiler shown in Figure 4.2 is a vertical array of hi vol filtration devices attached to a mobile support tower. The intake area of each filtration

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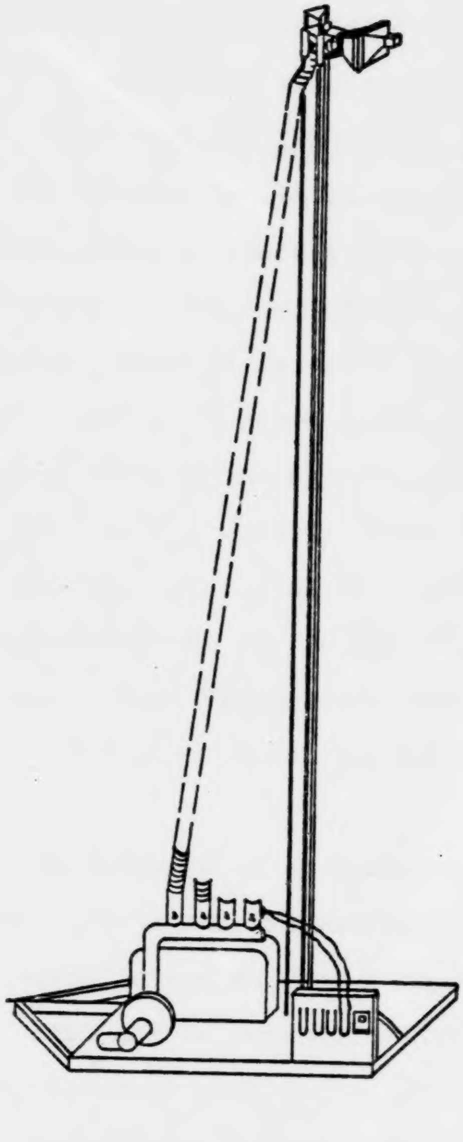

Figure 4-2. MRI vertical profiler.

unit is reduced to allow isokinetic sampling. A flexible hose (4 in. diameter) connects each sampler to a suction manifold. Each leg of the manifold is fitted with a calibrated orifice and a butterfly valve for flow control. The vacuum source is a 2-hp centrifugal blower. Electrical power is supplied by a gasoline engine generator.

4.2.4 Hi Vol with Andersen Head Modification

A modification of the standard hi vol sampler has been developed for detecting size distribution of total suspended particulates. The Andersen cascade impactor is designed to fit a standard hi vol. It has five, glass fiber, impaction surfaces followed by a glass fiber back-up filter. The impactor design separates particulate matter into five aerodynamic size ranges: 7 µm or larger, 3.3 to 7 µm, 2.0 to 3.3 µm, 1.1 to 2.0 µm, and 0.01 to 1.1 µm. Several types of cascade impactors exist.[9] Not all of the available types give comparable results. The principal of impaction varies, as does the size ranges of the particles collected.

4.2.5 Beta Guage[9]

A beta guage sampler consists of a two-stage collection system for respirable dust measurements and a beta absorption unit. The first stage is a cyclone precollector for retention of the non-respirable fraction of the dust. The precollector retains particles larger than about 10 µm in diameter. Particles not retained by the cyclone are collected by the second stage, which is a circular nozzle impactor-beta absorption assembly with an impaction disc. Particles collected by impaction on a plastic disc film increasingly absorb beta radiation reaching a Geiger detector from a carbon-14 source. The penetration of beta radiation relates directly to the mass per unit area of the disc. Beta guages have been applied in sampling programs where short-term, i.e. a few minutes as opposed to several hours, measurements of respirable dust fractions is desirable.

4.3 SPECIAL CONSIDERATIONS

Monitoring fugitive dust sources like those identified for surface mining involves some special problems. These problems relate to the nature of the emission sources, to changes in source activity, and to variations in meteorological conditions and the influence of those conditions on particle transport. No single publication summarizes the special problems associated with the fugitive dust sources that have been mentioned. Reports from individual source studies provide the best source of information.

Special problems associated with the nature of the emission sources can affect the sampling schedules, the choice of monitor for these sources, and the choice of monitoring site. The degree of control at the source may preclude the necessity to monitor the source. For example, experience shows that aggregate storage piles that are wet are not subject to wind erosion effects. Consequently, monitoring around wet storage piles is not needed. Experience also shows that loading and unloading operations are the major sources of emissions around storage piles. Thus, scheduling monitoring to include periods of reasonable activity is important.

Other sources, such as unpaved roads, might require isokinetic sampling to trap larger particles that might be missed by conventional hi vol methods. Sampling rates, sampling time, and wind speed are key factors in a case like this.

Data interpretation will be influenced by variables such as meteorological conditions. Wind erosion effects are influenced by wind speed, for example. In addition, wind direction and activities at other sources will influence monitoring results at a particular site. Rainfall and other precipitation will alter the emissions from these sources, and time averaging may not be possible.

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5.0 HEALTH AND WELFARE EFFECTS

5.1 FUGITIVE DUST

The existence of fugitive dust has been known for some time, however its impact on air quality was not quantified until 1972. At that time, emission factors were developed which indicated that fugitive dust represents a significant portion of the total particulate matter emissions in some Southwestern AQCR's. For example, in the Phoenix AQCR, it has been estimated that fugitive dust emissions contribute approximately 90% of the total suspended particulate (TSP) emissions in the AQCR. Control strategies based upon emission inventories which include fugitive dust emissions indicate that in order to attain national standards, unpaved roads need to be paved and windblown dust from exposed soil needs to be reduced by soil conservation measures or be stabilized such that soil erosion (i.e., windblown emissions) is minimized. Such measures are in addition to the more traditional stationary source controls.

The specific health impact of fugitive dust on human health is generally unknown. No epidemiological studies have been conducted in areas where the TSP concentration is high due to fugitive dust. Specific information on the chemical make-up of TSP in these areas is not available; however, the toxic fraction of the TSP is very likely to be small. On the other hand, dust from unpaved roads may contain high concentrations of lead and other heavy metals from automobile exhaust. Further, windblown dust from farmlands may contain various pesticides and herbicides that may be potentially toxic. Dust from tailings piles near smelters may also be high in heavy metals.

Since no information exists to say there is no health problem due to fugitive dust, nor is there information to define a special paraticulate matter standard for these areas, the current national standard, though imperfect, provides the best available standard to protect public health. Hence attainment of the current national standard should be the goal everywhere including fugitive dust areas. It should be noted that any attempt to develop a new standard for any pollutant is a long-term project (i.e., 5 to 7 years); hence, such an activity does not alleviate the current problems associated with fugitive dust. Currently, EPA is investigating the need for national standards for various toxic components of TSP, such as sulfates and nitrates, which may have some impact on approaches to TSP control in fugitive dust areas.

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5.2 FUGITIVE DUST FROM MINING

The effects of the particulate emissions from surface mining fugitive dust sources may be similar to the effects of particulates from natural fugitive dust emission sources. Neither type of particles has been studied extensively to characterize the impacts on public health or welfare. Urban particulates have been studied more extensively and correlations between ambient particulate concentrations and morbidity and mortality rates have led to the establishment of ambient air criteria.

For some of the fugitive dust source types for which emission factors have been derived, particle size determinations were made as part of the emission testing studies. A significant portion of the emissions for these sources were determined to be in the size range of particles that are transported outside of the source boundaries. If the mining operations in an area are substantial, and other types of industry are medium or light in comparison, then the emissions from the mining operations might be expected to have a considerable impact on the local air quality. Thus, the respirable portion of those emissions would be expected to contribute to pulmonary problems among the local population. Directional sampling and tracer studies could provide the necessary data to determine the total particulate impact from source mining on regional health and welfare.

6.0 RESEARCH AND DEVELOPMENT PROGRAMS

This section briefly describes the research and development programs involving fugitive dust from mining which are either on-going or in planning stages. Information on these R & D programs was obtained by contacting the various agencies which are concerned with mining activities - Bureau of Mines, Mining Enforcement and Safety Administration, various EPA laboratories, and others. Brief descriptions of these programs appear below.

> Open Source Assessment, part of EPA Contract 68-02-1874 with the Resources Extraction and Handling Division of the Industrial Environmental Research Laboratory/Cincinnati, by Monsanto Research Corporation.

The objective of this project is to provide the data necessary for planning EPA future action in developing control technology for open sources of emissions. Effects on public health are emphasized through five major criteria. These are source severity, source contribution to national emissions burden, contribution to individual state's emissions burdens, population affected and industrial emissions growth or decline using current technology. Open mining sources include sand and gravel, coal storage, clay mining, phosphate rock mining, open coal mining, crushed traprock and stone, crushed granite, crushed quartzite and refractory stone, crushed limestone, and coal refuse piles. Other sources are planned.

Quantification of Fugitive Process Emissions, EPA Contract, Office of Air Quality Planning and Standards, Research Triangle Park. by PEDCo Environmental Specialists, Inc.

EPA has issued a task order for approximately two man years of effort to identify industries which have a significant amount of fugitive emissions emanating from their processes (through roof vents, off conveyor belts, from material storage areas, from unhooded reaction vessels, etc.). The work plan has not been prepared yet, but it is expected that several of the unit operations found in mines will be investigated as part of this study. However, no sampling will be conducted and it is doubtful that information from the literature search will uncover any additional emission factors for mining operations beyond those given in the Task 1 report of this project. Emission data from similar processes used in other industries may be adapted for application to mining operations.

Water Infusion of Coalbeds, RFP No. Jo366051, U.S. Bureau of Mines.

This study will evaluate the effect of water infusion of coalbeds on respirable dust generated during mining operations. Infusion work will be conducted on either development sections (less than 500 feet wide) or longwalls.

Coalbeds in the Beckley, West Virginia area will be the area of study.

Study to Develop Emission Factors for Surface Coal Mines, EPA Region VIII Energy Office.

AQMA analyses for several of the energy development areas in Region VIII showed that intensive coal mining will potentially cause air quality standards to be exceeded in these areas. Therefore, the Region VIII Energy Office has allocated money to fund a project to sample particulate emissions at three different coal mines and develop more accurate emission factors for mining operations than those currently available. The scope of work for this proposed contractual effort has been drafted and approved within EPA, but has not yet been released in the form of an RFP. It is anticipated that this contract would be awarded sometime during the summer or fall of 1976 and the field work would be conducted during calendar 1976. The sampling approach that will probably be used in this project is to locate high volume samplers at different distances downwind from the mining sources, plus one sampler upwind to establish background concentrations and then to calculate emission rates from the measured ambient loadings using Gaussian dispersion equations.

Surface Environment and Mining (SEAM) Studies, by the Forest Service's Intermountain Forest and Range Experiment Station, Ogden, Utah.

Three SEAM mining research studies are either underway or in planning stages. EPA is funding selected portions of these studies which are energy-related through Subagreement 77BED. These studies are briefly described below:

Methodology for Assessing the Environmental Impacts of Mining Roads and Road Construction on Water Quality, Hydrologic Effects, and Fugitive Dust, by grant to Montana State University.

This SEAM study is currently active to identify and assess the environmental impacts of four mining-related transportation systems: haul roads, railroads, pipelines, and electrical transmission lines. This research effort has been reoriented to concentrate on the effects of roads and road construction on the water resource and the fugitive dust problem. The study will identify characteristics of the road system and relate these to on-site data on climate, soils, topography, vegetation, etc. by means of mathematical relationships whenever possible. The result will be quantitative estimates of the impact of road construction on the quality, quantity, and peak flow of both ground water and surface water, and estimates of the amount of fugitive dust that may be expected.

Impact Assessment of Roads on the Hydrologic Regimen of Streams, including Sediment Loads. In-house research effort by the Forest Service.

s proposed SEAM study would measure the effect of the sediment loads, streamflow peaks, and channel y of streams that cross haul roads, both off-site oads and on-site mine roads. This effort would ate on the effect of roads because this is the most ransportation mode associated with coal and oil rface mining.

ermination of the Erodibility of Raw Spoils and
soil by Wind and Measurement of Fugitive Dust from
ing Roads, by grant to Montana State University.

s SEAM study is proposed in response to the interest n wind erosion of spoil and topsoil materials and in tive dust problem from mining roads. The erodi- f raw spoils and topsoil material subject to wind will be measured. In addition, other measurements made of the fugitive dust from mining roads.

Pollution Research in Western Surface Coal Mining
as - planned project for the Resources Extraction
Handling Division of the Industrial Environmental
earch Laboratory/Cincinnati, by Mathematica, Inc.
h ambient sampling by Hittmann Associates.

s project would monitor fugitive dust levels at four der varying climatic conditions, and use the results op and validate mathematical models that can be used ate dust levels as a function of climatic, topog- and geologic factors. Ambient dust levels in geographic areas will be compared with the dust n active surface mining areas, thereby determining the extent and magnitude of the fugitive dust conditions caused by mining. Effectiveness of existing dust control procedures as they are employed at active mines will be evaluated. New dust control procedures for surface mining operations will be recommended if needed. Analytical tools will be developed that can be used to estimate dust levels as a function of various physical factors.

Development of a Manual of Testing for Fugitive Dust Sources and Related Fugitive Dust Assessments, for EPA's Process Measurements Branch, Industrial Processes Division, Industrial Environmental Research Lab, Research Triangle Park, by the Research Corporation of New England.

This on-going multi-media study will assess fugitive dust emissions from both process and open sources. The study will take three years and is budgeted for $250,000. A manual of testing methodology will be developed, including quasi-stack monitoring, roof monitoring, and upwind-downwind techniques. In addition, the feasibility of employing remote sensing techniques to replace upwind-downwind sampling will be explored in several source areas.